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Great Lakes Water Quality Sixth Annual Report 1977: Appendix D Annual Report of the Radioactivity Subcommittee to the Implementation Committee, Great Lakes Water Quality Board

Great Lakes Water Quality Board. Radioactivity Subcommittee

GREAT LAKES
WATER QUALITY BOARD

INTERNATIONAL
JOINT
COMMISSION

GREAT LAKES WATER QUALITY 1977
APPENDIX D
RADIOACTIVITY SUBCOMMITTEE REPORT

GREAT LAKES WATER QUALITY

SIXTH ANNUAL REPORT

APPENDIX D

ANNUAL REPORT OF THE RADIOACTIVITY SUBCOMMITTEE

TO THE
IMPLEMENTATION COMMITTEE
GREAT LAKES
WATER QUALITY BOARD
JULY 1978

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PREFACE

Appendix D to the 1977 Annual Report on Great Lakes Water Quality is the third annual report submitted by the Radioactivity Subcommittee to the Implementation Committee and to the Great Lakes Water Quality Board. The Appendix contains detailed information and data available as of May 1978 regarding radioactivity in the Great Lakes Basin. A summary of this Appendix appears in the Board's Sixth Annual Report to the International Joint Commission.

Though the Board has reviewed and approved the Subcommittee's report for publication, some of the specific conclusions and recommendations contained in this Appendix may not be supported by the Board.

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1 INTRODUCTION

The Radioactivity Subcommittee reports annually to the Implementation Committee of the Water Quality Board on the radiological status of the Great Lakes. This report presents data on levels of radioactivity in water and biota collected during 1977. Discharges of nuclear waste from nuclear facilities in the Great Lakes Basin are also tabulated.

The status of the proposed refined radioactivity objective for Great Lakes water quality is decribed in Chapter 2. In Chapter 4 are details of the subcommittee's surveillance program to determine compliance with this proposed objective and to detect any trends in radioactive water quality. The factors used to convert the concentrations of selected radionuclides to the radiological dose (TED_{50}) received by an individual drinking the water are given in Chapter 3.

Figure 1 shows the geographical locations of all nuclear facilities in the Great Lakes Basin. Nuclear generating stations in the Great Lakes Basin have an installed electrical generating capacity of 13,378 MW. Table 1 provides details of each facility. Stations currently under construction or planned to be in operation within the next decade have a designed electrical generating capacity of 27,810 MW. Information regarding their locations, generating capacity, and completion dates is given in Table 2.

In the Great Lakes Basin, other stages of the nuclear fuel cycle which can have an impact on Great Lakes water quality are mining and milling of uranium, refining of uranium and conversion to UF_6, and reprocessing of spent nuclear fuel. Uranium mining and milling operations are carried out in the Elliot Lake area which drains to the North Channel via the Serpent River. Port Hope, on the north shore of Lake Ontario, is the site of the uranium refinery and UF_6 plant which dispose of their radioactive wastes at the nearby Port Granby waste management area.

Irradiated fuel from nuclear stations is currently stored on site until governmental policies in both the U.S. and Canada on its final disposition are finalized. However, irradiated uranium fuel was reprocessed at the Nuclear Fuel Services (NFS) plant at West Valley, New York, until 1971. Large quantities of radioactive waste are stored there. The NFS site drains to Lake Erie via Cattaraugus Creek, entering the lake southwest of Buffalo.

Medical, educational, and industrial uses of radioisotopes are a potential source of radionuclides that could reach the Great Lakes after passing through municipal waste treatment plants. This possibility is being investigated in the Lake Ontario Basin.

TABLE 1

OPERATING NUCLEAR GENERATING STATIONS, 1977

LAKE	STATION	LOCATION	REACTOR TYPE	ELECTRICAL POWER, MW
MICHIGAN	Zion I & II	Zion, Illinois	PWR	2 X 893
	Kewaunee	Carlton, Wisconsin	PWR	541
	Point Beach I & II	Manitowoc County, Wisconsin	PWR	2 X 497
	Palisades	Covert Township, Michigan	PWR	700
	Big Rock Point	Charlevoix County, Michigan	BWR	75
	Cook 1	Benton Harbor, Michigan	PWR	1060
HURON	Douglas Point	Kincardine, Ontario	CANDU	220
	Bruce A	Kincardine, Ontario	CANDU	4 X 750[a]
ERIE	Davis-Besse 1	Ottawa County, Ohio	PWR	906
ONTARIO	Pickering 1-4	Pickering, Ontario	CANDU	4 x 540
	Ginna	Ontario, New York	PWR	490
	Fitzpatrick	Oswego, New York	BWR	821
	Nine Mile Point 1	Oswego, New York	BWR	625

a. Units 1, 2, and 3 only. Unit 4 is expected to come on line in 1978.

TABLE 2

NUCLEAR GENERATING STATIONS UNDER CONSTRUCTION OR PLANNED

LAKE	STATION	LOCATION	REACTOR TYPE	ELECTRICAL POWER, MW	ESTIMATED COMPLETION DATE
MICHIGAN	Bailly 1	Westchester Township, Indiana	BWR	645	1979
	Cook 2	Benton Harbor, Michigan	PWR	1060	1978
HURON	Midland 1 & 2	Midland, Michigan	PWR	2 X 818	1980-82
	Bruce B	Kincardine, Ontario	CANDU	4 X 750	1982-84
	North Channel	Ontario	CANDU	4 X 850	1988
ST. CLAIR RIVER	Greenwood 2 & 3	St. Clair County, Michigan	PWR	2 X 1200	1985
ERIE	Fermi 2	Monroe County, Michigan	BWR	1093	1979
	Davis-Besse 2 & 3	Ottawa County, Ohio	PWR	2 X 906	1981-84
	Erie 1 & 2	Erie County, Ohio	PWR	2 X 1282	1985
	Perry 1 & 2	Perry County, Ohio	BWR	2 X 1205	1983
ONTARIO	Nine Mile Point 2	Oswego, New York	BWR	1080	1983
	Sterling 1	Sterling, New York	PWR	1150	1985
	Pickering 5-8	Pickering, Ontario	CANDU	4 x 540	1981-83
	Darlington	Oshawa, Ontario	CANDU	4 X 850	1985-88

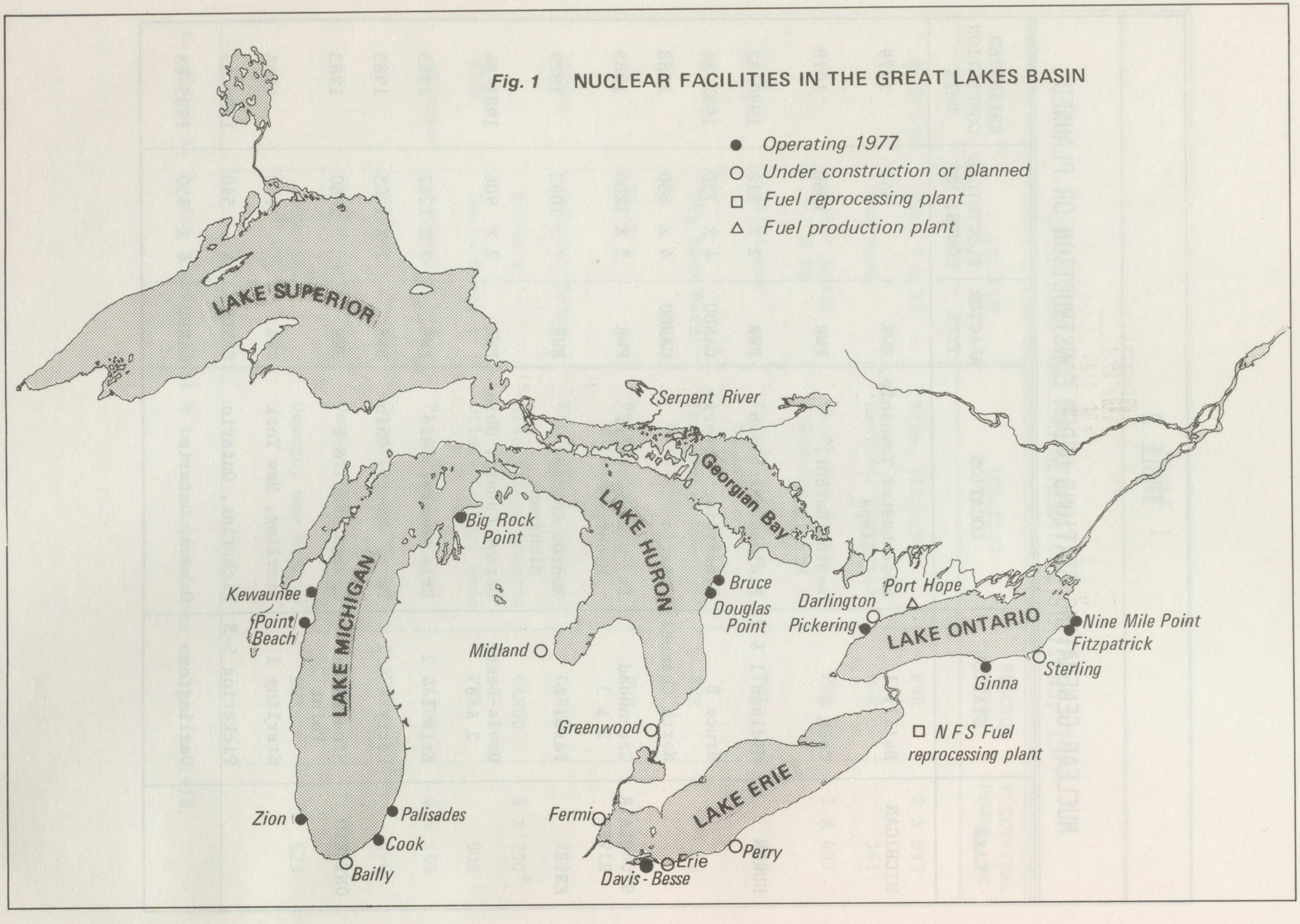

Fig. 1 NUCLEAR FACILITIES IN THE GREAT LAKES BASIN

2 STATUS OF PROPOSED RADIOACTIVITY OBJECTIVE

In the fall of 1975, a refined water quality objective for radioactivity in the Great Lakes was developed through collective meetings and exchanges of ideas between Canadian and United States advisory groups appointed by the two Governments. The resulting proposed objective was submitted to the appropriate departments of both Governments for review by all parties concerned with the radioactive water quality of the Great Lakes.

The Radioactivity Subcommittee (RSC) requested early ratification of this proposed objective in its 1975 and 1976 annual reports so that it could determine whether the water quality of the Great Lakes met the objective. Data on radioactivity levels in Great Lakes waters are submitted annually to the RSC by agencies responsible for monitoring programs in their jurisdictions.

The review process has been completed by both Governments and the proposed objective was brought forward in 1978 by both negotiating committees for discussion during the five-year review of the Great Lakes Water Quality Agreement. It is expected that the refined radioactivity objective will be incorporated into the revised Agreement.

The full text of the proposed objective is given in Appendix I.

3 DOSE CONVERSION

The proposed refined radioactivity objective for the Great Lakes waters is based on the radiological dose received by individuals imbibing lake water. Therefore, it is necessary to convert concentrations of radionuclides in the water to total equivalent dose (TED_{50}) to the International Commission on Radiological Protection's (ICRP) standard man. An interim list of conversion factors was given in the 1976 Appendix D (1). It was expected that ICRP would publish a new set of recommendations in 1977, thus necessitating a change in the method of calculating total equivalent dose. It was also expected that ICRP would publish refined calculations of the doses produced when various radionuclides were ingested.

The ICRP published its new recommendations (2), but likely will not publish its refined dose calculations until 1979. Therefore, the interim dose conversion factors given last year were recalculated to conform to the new recommendations and will be used until refined calculations are available. This list, given in Table 3, does not include some other radionuclides of lesser importance which may be needed occasionally.

These recommendations differ from earlier ones in the way dose to a particular organ or tissue is related to the whole body dose. Previously, the limiting dose to an individual was that received by the most sensitive organ. The dose limit for this critical organ was set equal to, or at some multiple of, that for the whole body. The ICRP now recommends that the risk be equal, whether the whole body is irradiated uniformly or non-uniformly. Therefore, the detriments to individual organs or tissue must be capable of summation. To accomplish this, a weighting factor, W_T, is applied to each tissue. The value of W_T represents the proportion of the risk resulting from tissue (T) to the total risk, when the body is irradiated uniformly. This can be expressed as

$$\sum_T W_T H_T \leq H_{wb,L}$$

where H_T is the annual dose equivalent in tissue (T) and $H_{wb,L}$ is the annual dose equivalent limit for uniform irradiation of the whole body.

TABLE 3

DOSE CONVERSION FACTORS

RADIONUCLIDE	TISSUE AT RISK	TISSUE (mrem/a per pCi/L)	PROPORTION OF RISK FROM TISSUE TO WHOLE BODY RISK (W_T)	EQUIVALENT WHOLE BODY TED_{50} (mrem/a per pCi/L)
^{3}H	Whole body	0.000064	1	0.000064
^{90}Sr	Red bone marrow	0.46	0.12	0.079
	Bone surfaces	0.80	0.03	
^{226}Ra	Bone Surfaces	9.1	0.03	0.43
	Red bone marrow	1.3	0.12	
^{134}Cs	Whole body	0.055	1	0.055
^{137}Cs	Whole body	0.025	1	0.025
^{129}I	Thyroid	7.5	0.03	0.23
^{131}I	Thyroid	1.5	0.03	0.045
^{60}Co	Lower large intestine	0.03	0.06	0.0018
^{58}Co	Lower large intestine	0.015	0.06	0.0009
^{65}Zn	Liver	0.015	0.06	0.0009
^{95}Zr	Lower large intestine	0.025	0.06	0.0015
^{106}Ru	Lower large intestine	0.15	0.06	0.009
^{125}Sb	Lower large intestine	0.015	0.06	0.0009
^{144}Ce	Lower large intestine	0.15	0.06	0.009
^{54}Mn	Lower large intestine	0.015	0.06	0.0009

The values of W_T recommended by ICRP are:

TISSUE	W_T
Gonads	0.25
Breast	0.15
Red Bone Marrow	0.12
Lung	0.12
Thyroid	0.03
Bone Surfaces	0.03
Remainder (other tissues or organs)	0.30

The remainder (0.30) is allocated equally to the five other organs or tissues receiving the highest dose equivalent. When the gastro-intestinal tract is irradiated, the stomach, small intestine, upper large intestine, and lower large intestine are treated as four separate organs.

The dose equivalent, H_T, at a point in a tissue, is given by

$$H_T = DQN$$

where D is the absorbed dose, Q is the quality factor applicable to the absorbed radiation, and N is the product of all other modifying factors. For the present, N = 1. The following effective values of Q have been recommended for the various types of primary radiation:

RADIATION	Q
X rays, γ rays, and electrons	1
Neutrons and protons	10
α particles	20

The new name for the unit of dose equivalent is the sievert (Sv).

$$1 \text{ Sv} = 100 \text{ rem}$$

The units of the sievert are joules per kilogram. The proposed radioactivity objective is expressed in terms of the committed dose equivalent to the whole body over a 50-year period following the annual intake of 803 litres of lake water (TED_{50}). To meet this requirement, H_T is calculated using the 50-year retention integral, $H_{wb,L}$ becomes the numerical value for the ambient water quality objective, a TED_{50} of 1 mrem (10 μSv).

The conversion factors from radionuclide concentration to dose equivalent in the tissue given in the 1976 Appendix D have been recalculated using ICRP's 1977 recommendations. These are shown in Table 3 along with the specific tissues involved and their weighting factors. The values for ^3H, ^{90}Sr, and ^{226}Ra are based on calculations provided by Dr. J. Muller (3) and are adjusted for the ICRP-recommended Q values and a 2.2 litre daily water intake. The values for the remaining radionuclides are based on EPA's dosimetric calculations for the United States National Interim Primary Drinking Water Regulations (4), adjusted for a 2.2 litre daily intake of water. The major changes are in the values for ^{3}H, where a decrease in Q from 1.7 to 1 decreases the dose; and for ^{226}Ra, where an increase in Q from 10 to 20 increases the dose to the specific tissues.

4 RADIOACTIVITY SURVEILLANCE

PRESENT GREAT LAKES PROGRAMS

Ongoing radioactivity monitoring programs are essentially oriented towards public health protection using state, provincial, and federal criteria. However, monitoring at most locations has been tailored to meet requirements of the proposed radioactivity objective for the Great Lakes (e.g. source control areas). Thus, the data which jurisdictions annually collect and forward to the Radioactivity Subcommittee provide a sound base for assessing the Great Lakes radioactive water quality. Details of the present monitoring programs by agency were provided in the 1976 Appendix D (1).

PROPOSED RADIOACTIVITY SURVEILLANCE PROGRAM

Current monitoring programs on the Great Lakes mainly involve screening analyses employing gross α and gross β measurements. Although these analyses ensure that jurisdictional criteria are not being exceeded, they are of little value in determining radiological dose from imbibition of the water, the basis for the proposed radioactivity objective. To measure compliance with this objective, a radioactivity surveillance program, which would be coördinated with the Surveillance Subcommittee's overall plan, was outlined in the 1975 Appendix D (5). The requirements of this program include specific analyses for radionuclides with detection limits sufficiently low to enable effective determination of the contribution to the radiological dose objective from a particular radionuclide. Specific radionuclides most likely expected from individual nuclear operations are shown in Table 4 and currently proposed detection limits are given in Table 5.

Upgrading of analytical facilities to carry out this program will be expensive and operating costs of the analytical program will be higher than current monitoring projects. A detailed description of this proposed plan for each of the Great Lakes, including sampling locations, frequency of sampling, and radionuclides analyzed, is given in Appendix II. Also included are each jurisdiction's estimate of the costs involved in, first, upgrading the analytical capability of the laboratory to the standards required for the surveillance program and, second, operating the program each year. The estimates do not include costs incurred by agencies involved in research programs which are designed to either define key radionuclides representative of specific locations in the Great Lakes or monitor potential problem areas such as municipal waste treatment plants which might receive wastes from medical and educational users of radionuclides.

TABLE 4

MAJOR RADIONUCLIDES ASSOCIATED WITH INDIVIDUAL NUCLEAR OPERATIONS

HEAVY AND LIGHT WATER REACTORS	MINING AND REFINING	REPROCESSING	FALLOUT
^{3}H	^{226}Ra	^{3}H	^{3}H
^{134}Cs	^{228}Ra	^{137}Cs	^{137}Cs
^{137}Cs	^{230}Th	^{134}Cs	^{90}Sr
^{131}I	^{210}Pb	^{106}Ru	
Other γ-ray emitting fission and neutron activation products		^{129}I	
		^{144}Ce	
		^{90}Sr	

TABLE 5

RECOMMENDED LOWER LIMITS OF DETECTION FOR RADIONUCLIDES IN GREAT LAKES WATERS

RADIONUCLIDE	RECOMMENDED LLD[a] (pCi/L)
^{226}Ra	0.2
^{90}Sr	1.3
^{3}H	400[b]
^{134}Cs	2
^{137}Cs	4
^{131}I	2.2
^{129}I	0.4
^{106}Ru	11
^{144}Ce	11
^{60}Co	56
^{95}Zr	67
Other fission and activation products	>100

a. Equal to one tenth of the concentration producing a TED_{50} of 1 mrem.

b. Value which usually can be achieved for liquid scintillation counting.

RECENT CHANGES IN LEGISLATION

The U.S. Clean Air Act was amended by P.L. 95-95 in 1977. Section 122 of the amendments introduces regulatory control over the emission of radioactive pollutants to the atmosphere. Regulation can be in the form of a standard or an emission limitation. These would be subject to review and approval by the U.S. Nuclear Regulatory Commission. The section also requires the U.S. Environmental Protection Agency to study the effects on public health and welfare of an array of presently unregulated materials, including radioactive pollutants.

5 RADIONUCLIDE DISCHARGES FROM NUCLEAR FACILITIES IN 1977

RELEASES FROM NUCLEAR GENERATING STATIONS

As a condition of its licence, a nuclear generating station must report annual releases of radionuclides to the responsible federal regulatory agency. Gaseous and aqueous releases for 1977 are tabulated in Tables 6 and 7, respectively.

RELEASES FROM NUCLEAR FUEL REPROCESSING PLANTS

Although the Nuclear Fuel Services, Inc. fuel reprocessing plant at West Valley, New York, has not processed irradiated fuel since 1972, radionuclides are continuously discharged to Cattaraugus Creek, which drains to Lake Erie. Table 8 gives the quantities of radionuclides discharged during 1977.

RELEASES FROM URANIUM MINING, MILLING, AND REFINING

Radium and thorium radioisotopes are leached from uranium mine tailings by surface water in the Elliot Lake area. A large fraction of this radioactivity is precipitated in settling ponds by the addition of lime and barium chloride, but the remainder reaches the Serpent River by direct flow over, and seepage through, tailings pond dams. Although the total discharges to the Serpent River are not quantified, it is possible to estimate the loadings of ^{226}Ra to the North Channel from the concentration and flow data recorded near the river mouth. ^{226}Ra concentrations for five samples taken during 1977 are given in Table 13 along with the average flow rates for the days the samples were collected. An average annual loading of ^{226}Ra is shown in Table 8.

The quantity of ^{226}Ra discharged from Eldorado Nuclear Ltd's. Port Granby waste management site to Lake Ontario is also given in Table 8. Discharge decreased after July 1977 because dams were installed on the two creeks draining the site, and a treatment facility began to remove ^{226}Ra before discharging the runoff to the lake.

RELEASES FROM OTHER NUCLEAR FACILITIES

The quantities of radionuclides actually purchased by medical and industrial license holders and discharged to sewers after use are not recorded by the United States Nuclear Regulatory Commission, the Atomic Energy Control Board of Canada, or "agreement states" which regulate some non-reactor licencees. Therefore, the impact of these potential sources of radionuclide discharge to the Great Lakes cannot be predicted. However, since ^{99m}Tc is the main radionuclide purchased for medical use, its 6-hour half-life would preclude it from

TABLE 6

GASEOUS DISCHARGES FROM NUCLEAR GENERATING STATIONS - 1977[a]

STATION	ANNUAL RELEASE IN CURIES			
	PARTICULATES	^{131}I	NOBLE GASES	^{3}H
Big Rock Point	0.26	0.20	13,400	11
Bruce A	0.0025	0.0125	33,900	8,490
Cook 1[b]	0.000005	0.0006	110	0.01
Davis-Besse 1[c]	<0.0002	<0.00001	<1,100	<0.0006
Douglas Point	0.00017	0.0009	8,692	11,806
Fitzpatrick[b]	0.02	0.08	15,000	4.7
Ginna	0.00007	0.02	3,200	50
Kewaunee	0.0007	0.02	2,400	3.8
Nine Mile Point 1	0.05	0.15	3,500	45
Palisades	0.001	0.02	60	2.2
Pickering	0.0072	0.0019	4,300	44,000
Point Beach 1 & 2	1.1	0.003	1,100	190
Zion 1 & 2	0.005	0.03	32,000	d

a. Information from References (6) and (7).

b. January through June 1977 only.

c. Went critical 30 November 1977.

d. Not available.

TABLE 7

AQUEOUS DISCHARGES FROM NUCLEAR GENERATING STATIONS - 1977[a]

STATION	ANNUAL RELEASE IN CURIES	
	FISSION AND ACTIVATION PRODUCTS	^3H
Big Rock Point	0.39	8.8
Bruce A	0.64	966
Cook 1[b]	0.9	120
Davis-Besse 1[c]	0.02	9
Douglas Point	0.21	1,983
Fitzpatrick[b]	0.24	1.4
Ginna	0.06	120
Kewaunee	1.3	290
Nine Mile Point 1	0.3	2.5
Palisades	0.09	56
Pickering	0.8	19,000
Point Beach 1 & 2	1.6	1,000
Zion 1 & 2	0.9	720

a. Information from References (6) and (7).

b. January through June 1977 only.

c. Went critical 30 November 1977.

being a problem. Studies to look for radionuclides leaving waste water treatment plants have been proposed at Buffalo and Rochester by the New York State Department of Environmental Conservation; at Toronto by the Ontario Ministry of the Environment and the Ministry of Labour; and at Hamilton by the Canada Centre for Inland Waters. Results from these special studies will be reported in next year's Appendix D.

TABLE 8

ANNUAL AQUEOUS DISCHARGES FROM OTHER NUCLEAR FACILITIES - 1977

SOURCE	LAKE	CURIES PER YEAR		
		^{3}H	^{90}Sr	^{226}Ra
Port Granby waste management site[a]	Ontario	-	-	0.0046 Jan.-July 0.0001 Aug.-Dec.
Elliot Lake uranium mining area via Serpent River	Huron-North Channel	-	-	1.42
Nuclear Fuel Services[b]	Erie	538	0.01	-

a. Information from Reference (7).

b. Information from Reference (12).

6 MONITORING DATA FOR 1977

The radiological monitoring data for water and biota samples obtained during 1977 are reported in Tables 9 to 22.

TABLE 9

DRINKING WATER INTAKES, 1977[a]

LAKE	SOURCE	SAMPLING LOCATION[b]	STATION NUMBER	MEAN CONCENTRATION IN pCi/L				
				GROSS α	GROSS β	^{3}H	^{90}Sr	^{137}Cs
MICHIGAN	Big Rock Point	Charlevoix[c]	DBD3	<2.5	2.2±2	-	<0.8	-
		Petoskey[c]	DBK4	<2.2	3.7±2	-	0.9±0.8	-
	Donald Cook	New Buffalo[c]	DCK5	<1.7	2.5±1	-	1.2±0.8	-
		Lake Township[c]	DCL7	<1.7	3.0±2	-	0.9±0.9	-
		Bridgman[c]	DCJ5	<1.7	3.2±2	-	1.1±0.9	-
	Palisades	South Haven[c]	DPB5	2.5	2.5±1	-	1.2±0.9	-
		Benton Harbor[c]	DPC1	<1.7	2.7±2	-	1.4±0.9	-
		St. Joseph[c]	DPH6	<1.7	2.8±1	-	1.4±0.8	-
	Bailly (proposed)	East Chicago	LM-EC	0.04±0.65	3.72±0.96	-	-	-
		Gary	LM-G	-0.26±0.54	3.07±0.93	-	-	-
		Hammond	LM-H	-0.08±0.64	3.25±0.96	-	-	-
		Michigan City	LM-M	-0.01±0.57	3.79±0.95	-	-	-
		Whiting	LM-W	-0.09±0.62	3.19±0.95	-	-	-
	Zion	Lake County	030205	<1	4±2	300±300	1±1	<5
		Waukegan	030206	<1	3±2	300±300	-	-
HURON	Bruce	Kincardine	-	-	-	-	0.64	0.03
		Port Elgin	-	-	-	-	0.68	0.02
ERIE	Fermi 1 & 2	Flat Rock[c]	DEF1	<2	4.5±2	-	<1.2	-
		Monroe[c]	DEJ1	<1.2	3.5±2	-	1.0±0.9	-
	Nuclear Fuel Services	Angola[c]	-	-	4	<300	-	-
		Sturgeon Point[c]	-	<3	4	<300	-	-
		Dunkirk[c]	-	-	3.2	-	-	-
ONTARIO	Pickering	Pickering	-	-	-	-	0.91	0.05
		Ajax	-	-	-	-	0.96	0.08
		Toronto	-	-	-	-	0.95	0.04
	Ginna	Ontario[d]	-	<3	4	313	-	-
	Fitzpatrick and Nine Mile Point	Oswego[c]	-	-	3.5	-	-	-
		Demster Beach[e]	-	-	5.5	<400	-	-

a. Information from References (8 - 12).
b. Raw water unless indicated.
c. Finished water
d. $^{131}I<3$ pCi/L; $^{125}I<0.3$ pCi/L.
e. Not a drinking water intake.

TABLE 10

OPEN LAKE DATA, 1977[a]

LAKE	STATION NORTH LATITUDE	STATION WEST LONGITUDE	SAMPLING DATE	DEPTH IN METRES	CONCENTRATION IN pCi/L ^{137}Cs	^{125}Sb	^{90}Sr
HURON	43°43'00"	81°57'00"	August 8	1	0.038±0.006	0.060±0.015	0.84±0.03
ERIE	42°34'30"	79°36'36"	September 1	1	0.014±0.005	0.041±0.014	0.69±0.02
				55	0.017±0.005	0.028±0.012	-
	42°09'00"	81°18'30"	September 1	1	0.030±0.006	0.028±0.010	0.95±0.02
				26	0.022±0.005	0.060±0.014	0.78±0.03
ONTARIO	43°25'02"	79°24'03"	August 18	1	0.010	0.025	0.84±0.02
				103	0.019±0.005	0.030±0.011	0.95±0.03
	43°35'40"	78°00'50"	August 18	1	0.026±0.005	0.038±0.013	1.14±0.02
				178	0.039±0.007	0.040±0.013	0.90±0.02
	43°36'24"	76°42'42"	August 17	1	0.029±0.006	0.054±0.012	0.86±0.02
				185	0.017±0.005	0.052±0.012	0.89±0.02

a. Information from Reference (13).

TABLE 11

LAKE MICHIGAN INSHORE SURFACE WATER, 1977[a]

SOURCE	SAMPLE LOCATION	SAMPLING DATE	SUSPENDED GROSS α	SUSPENDED GROSS β	SOLUBLE GROSS α	SOLUBLE GROSS β	SOLUBLE ^{131}I	SOLUBLE ^{137}Cs	SOLUBLE ^{90}Sr
Point Beach	Coast Guard Station	24 May	<1.4	<1.7	<4	3.7±1.2	<7	<7	<1.4
		16 Nov.	<1.4	2.3±1.2	<2.3	2.6±1.4	-	<7	<1.6
	Point Beach Site	24 May	<1.4	<1.7	<4	3.9±1.5	<7	<7	<1.1
		16 Nov.	<1.4	1.5±1.1	<2.3	2.9±1.4	-	<7	<1.2
	Green Bay Pumping Station	24 May	<1.4	<1.7	<4	3.6±1.4	<7	<7	<1.1
		16 Nov.	<1.4	<1.7	<2.3	2.1±1.3	-	<7	<1.3
Kewaunee	Kewaunee Site	24 May	<1.4	<1.7	<4	3.0±1.4	<7	<7	<1.1
		16 Nov.	<1.4	3.1±1.2	<2.3	2.4±1.4	-	<7	<1.5
	Two Creeks Park	24 May	<1.4	<1.7	<4	3.3±1.4	<7	<7	<1.4
		16 Nov.	<1.4	<1.7	<2.3	2.5±1.4	-	<7	<1.1

a. Information from Reference (14).

TABLE 12

LAKE MICHIGAN INSHORE SURFACE WATERS, 1977[a]

SOURCE	SAMPLING LOCATION	STATION NUMBER	CONCENTRATION IN pCi/L GROSS α	GROSS β	^3H
Big Rock Pt.	Mt McSauba Pt.	SB1	<1.8	3.2±1	300±200
	0.8 km south	SB2[b]	<1	5.0±1	400±200
	BRP Plant	SB3	<1.5	4.8±1	330±200
	0.8 km north	SB4	<1.3	3.6±1	320±200
	Nine Mile Pt.	SB5	<1.5	3.1±1	300±200
Donald Cook	Weko Beach	SC1	-	3.8±1	300±200
	0.8 km south	SC2	-	3.1±1	360±200
	Cook Plant	SC3	-	3.1±1	420±200
	0.8 km north	SC4	-	3.3±1	320±200
	Chalet on Lake	SC5	-	4.2±1	330±200
Palisades	Covert Twp. Park	SP2	-	4.4±1	340±200
	Palisades Plant	SP3	-	3.2±1	300±200
	Van Buren St. Park	SP4	-	4.6±1	300±200
	South Haven	SP5	-	4.4±1	270±200
	Roadside Park	SP6	-	4.1±1	330±200
Bailly (Proposed)	Burns Ditch	BD-O	-0.33±0.81	6.13±1.16	-
	Indiana Harbor Canal	IHC-1	-0.18±0.82	12.84±1.38	-
Zion	Unit 1 & 2 intake	030201	<1	6±2	500±300
	0.6 km north	030203	<1	5±2	300±300
	2.1 km north	030205[c,d]	<1	4±2	300±300
	0.1 km south	030207	<1	4±2	300±300
	9.6 km south	030206[d]	<1	3±2	300±300

a. Information from References (8-10).
b. γ-scan showed ^{137}Cs = 8±6 pCi/L on August 1 and 9±6 pCi/L on Oct. 3, 1977.
c. ^{89}Sr<1 pCi/L, ^{90}Sr = 1±1 pCi/L, γ-emitting fission and activation products < 5 pCi/L.
d. Public water supply intake.

TABLE 13

NORTH CHANNEL - SERPENT RIVER SURFACE WATER, 1977[a]

STATION	DATE	FLOW (m^3/s)	CONCENTRATION in pCi/L GROSS α	GROSS β	^{226}Ra	U (μg/L)
On Serpent River at Hwy. 17 bridge, 8.4 km upstream from harbour	25 Jan.	2.4	13	12	6	<10
	5 May	35.7	12	11	2	<10
	17 June	5.8	16	16	6	<10
	14 Aug.	1.2	16	21	6	<10
	28 Oct.	24.3	11	11	4	<10

a. Information from References (13) and (15).

TABLE 14

NORTH CHANNEL INSHORE SURFACE WATER
SERPENT HARBOUR, 1977[a]

STATION			SAMPLE DATE	DISTANCE FROM SOURCE (km)	CONCENTRATION IN pCi/L							U (µg/L)
NUMBER	NORTH LATITUDE	WEST LONGITUDE			GROSS α	GROSS β	^{226}Ra	^{228}Ra	^{232}Th	^{230}Th	^{228}Th	
274	46°12'15"	82°37'36"	May 21	0.4	17	16	6	b	b	b	b	<10
			Sept 8		8	12	2	<2	<1	<5	<1	<10
279	46°12'12"	82°38'22"	May 21	1.4	22	16	5	b	b	b	b	<10
			Sept 8		7	11	2	<2	<1	<5	<1	<10
281	46°12'11"	82°39'00"	May 21	2.2	17	16	6	b	b	b	b	<10
			Sept 8		3	5	1	<2	<1	<5	<1	<10
285	46°12'04"	82°40'00"	May 21	3.5	12	12	4	b	b	b	b	<10
			Sept 8		4	6	1	<2	<1	<5	<1	<10
286	46°11'45"	82°40'00"	May 21	3.7	11	11	2	b	b	b	b	<10
			Sept 8		1	3	<1	<2	<1	<5	<1	<10
288	46°11'38"	82°41'04"	May 21	5.3	11	11	3	b	b	b	b	<10
			Sept 8		3	5	<1	<2	<1	<5	<1	<10
291	46°10'53"	82°42'24"	May 21	7.0	7	6	1	b	b	b	b	<10
			Sept 8		1	3	<1	<2	<1	<5	<1	<10

a. Information from Reference (15).
b. Not analyzed.

TABLE 15

LAKE HURON INSHORE SURFACE WATER
DOUGLAS POINT N.G.S., 1977[a]

STATION			SAMPLING DATE	CONCENTRATION in pCi/L				
NUMBER	NORTH LATITUDE	WEST LONGITUDE		GROSS α	GROSS β	^{3}H	^{134}Cs	^{137}Cs
117	44°20'09"	81°35'42"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	7	<290	<40	<40
121	44°19'33"	81°36'50"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
122	44°20'02"	81°36'45"	June 3	<1	5	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
371	44°19'33"	81°36'27"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	3	<290	<40	<40
456	44°19'11"	81°36'34"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
457	44°19'38"	81°36'18"	June 3	<1	5	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
458	44°19'46"	81°36'13"	June 3	<1	6	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
459	44°20'09"	81°36'07"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40

a. Information from Reference (15).

TABLE 16

LAKE HURON INSHORE SURFACE WATER

BRUCE "A" N.G.S., 1977[a]

STATION NUMBER	STATION NORTH LATITUDE	STATION WEST LONGITUDE	SAMPLING DATE	CONCENTRATION in pCi/L GROSS α	GROSS β	^{3}H	^{134}Cs	^{137}Cs
372	44°20'36"	81°35'12"	June 3	<1	5	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
373	44°20'54"	81°35'21"	June 3	<1	5	<360		
			Aug. 3	<1	4	<290	<40	<40
461	44°20'30"	81°35'29"	June 3	<1	6	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
463	44°20'51"	81°34'44"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
468	44°21'04"	81°34'26"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
466	44°21'04"	81°35'03"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
467	44°21'07"	81°34'44"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40
469	44°20'55"	81°34'10"	June 3	<1	4	<360	<40	<40
			Aug. 3	<1	4	<290	<40	<40

a. Information from Reference (15).

TABLE 17

LAKE ERIE INSHORE SURFACE WATERS, 1977

SOURCE	SAMPLE LOCATION	CODE	MEAN CONCENTRATION IN pCi/L GROSS β	^{3}H
Fermi 1 & 2[a]	Fermi Plant	SE9	3.8±2	340±200
Nuclear Fuel Services	Niagara River (West Branch)	-	3.2±2	

a. Information from Reference (8).

TABLE 18

LAKE ONTARIO SURFACE WATER NEAR PORT HOPE AND OFF WELCOME AND PORT GRANBY DUMPS, 1977[a]

LOCATION	STATION NUMBER	DATE	CONCENTRATION IN pCi/L GROSS α	GROSS β	^{226}Ra	U (μg/L)
Inside Port Hope Harbour	06-09-029-1	31 May	75	30	2	45
		5 July	55	20	<1	30
		10 Aug.	90	115	3	<10
		1 Sept.	102	30	2	50
	06-09-029-2	31 May	40	25	2	25
		5 July	48	19	1	30
		10 Aug.	145	55	4	75
		1 Sept.	56	17	2	30
	06-09-029-3	31 May	40	25	3	25
		5 July	58	24	2	30
		10 Aug.	135	70	4	75
		1 Sept.	51	18	2	-
	06-10-001-1	31 May	66	26	1	45
		5 July	44	19	1	25
		10 Aug.	175	65	2	95
		1 Sept.	57	19	1	30
	06-10-001-2	31 May	50	25	3	30
		5 July	55	20	2	30
		10 Aug.	175	65	4	80
		1 Sept.	62	20	2	35
	06-10-001-3	31 May	50	20	2	30
		5 July	48	20	2	30
		10 Aug.	185	65	3	80
		1 Sept.	67	20	1	35
	06-10-001-4	31 May	5	3	1	<10
		5 July	30	11	1	20
		10 Aug.	5	6	<1	<10
		1 Sept.	45	13	2	25
Outside Port Hope Harbour	06-10-001-05	31 May	5	5	<1	<10
		5 July	1	4	<1	<10
		10 Aug.	<2	4	<1	<10
		1 Sept.	2	5	<1	<10
	06-10-001-06	31 May	<2	5	<1	<10
		5 July	15	5	<1	10
		10 Aug.	4	4	<1	<10
		1 Sept.	1	5	1	<10
	06-10-001-07	31 May	<2	4	<1	<10
		5 July	<2	3	<1	<10
		10 Aug.	2	3	<1	<10
		1 Sept.	<2	5	1	<10
Off Welcome Dump	6-11-001-01	31 May	<2	4	1	<10
		5 July	<2	4	<1	<10
		1 Sept.	<2	3	<1	<10
	6-11-001-02	31 May	<2	3	<1	<10
		5 July	<2	4	<1	<10
		1 Sept.	2	5	<1	<10
	6-11-001-03	31 May	1	3	<1	<10
		5 July	1	4	<1	<10
		1 Sept.	<2	4	<1	<10
Off Port Granby Dump	6-11-002-01	31 May	1	4	<1	<10
		5 July	1	4	<1	<10
		1 Sept.	1	4	1	<10
	6-11-002-02	31 May	<2	4	<1	<10
		5 July	2	4	<1	<10
		1 Sept.	3	5	<1	<10
	6-11-002-03	31 May	<2	3	<1	<10
		5 July	2	4	<1	<10
		1 Sept.	1	5	1	<10

a. Information from Reference (15).

TABLE 19

LAKE ONTARIO SURVEY OFF PORT GRANBY WASTE MANAGEMENT SITE - JUNE 21, 1977[a]

TRANSECTION	DISTANCE FROM SHORELINE (metres)	^{226}Ra (pCi/L)
200 m east of East Creek	0	0.104±0.006
	75	0.180±0.010
	150	0.046±0.005
	225	0.036±0.006
East Creek	0	2.56±0.04
	75	0.033±0.005
	150	0.025±0.005
	225	0.034±0.006
West Creek	0	7.23±0.07
	75	0.024±0.003
	150	0.025±0.005
	225	0.028±0.005
200 m west of West Creek	0	0.19±0.01
	75	0.022±0.005
	150	0.033±0.005
	225	0.027±0.005

a. Information from Reference (20).

TABLE 20

LAKE ONTARIO INSHORE SURFACE WATER

PICKERING "A" N.G.S., 1977[a]

STATION			SAMPLING DATE	CONCENTRATION in pCi/L				
NUMBER	NORTH LATITUDE	WEST LONGITUDE		GROSS α	GROSS β	^{3}H	^{134}Cs	^{137}Cs
1659	43°48'33"	79°04'40"	May 31	<1	8	<360	<40	<40
			Nov 28	<1	3	2060±140	<40	<40
1660	43°48'25"	79°04'32"	May 31	<1	7	540±170	<40	<40
			Nov 28	<1	2	1600±130	<40	<40
1661	43°48'35"	79°05'03"	May 31	<1	6	560±170	<40	<40
			Nov 28	<1	7	1880±130	<40	<40
1662	43°48'25"	79°05'00"	May 31	<1	4	<360	<40	<40
			Nov 28	<1	8	1270±130	<40	<40
1663	43°48'15"	79°04'51"	May 31	<1	6	<360	<40	<40
			Nov 28	<1	2	1220±130	<40	<40
1664	43°48'09"	79°04'40"	May 31	<1	6	<360	<40	<40
			Nov 28	<1	2	1170±130	<40	<40
1665	43°48'07"	79°04'08"	May 31	<1	5	<360	<40	<40
			Nov 28	<1	1	<260	<40	<40
1666	43°48'19"	79°03'52"	May 31	<1	7	<360	<40	<40
			Nov 28	<1	3	<260	<40	<40

a. Information from Reference (15).

TABLE 21

LAKE ONTARIO FISH IN VICINITY OF

NUCLEAR GENERATING STATIONS IN NEW YORK, 1977[a]

LOCATION	CONCENTRATION IN pCi/kg (WET WEIGHT)					
	^{90}Sr	^{131}I	^{134}Cs	^{137}Cs	^{106}Ru	^{40}K
Ginna N.G.S. - 300 m offshore[b]	4±2	<30	11±9	70±12	<50	2500±200
	28±2	-	<8	51±10	<40	2300±180
Nine Mile Point N.G.S. - 300 m offshore[c]	16±1	-	<7	55±9	<50	1740±150

a. Information from Reference (12).
b. Top feeder. Analysis on whole fish.
c. Bottom feeder. Analysis on whole fish.

TABLE 22

LAKE ONTARIO FISH (RAINBOW TROUT) FROM MOUTH OF GANARASKA RIVER[a]

COLLECTION DATE	MASS OF WHOLE FISH (kg)	SEX	CONCENTRATION IN pCi/kg (WET WEIGHT)	
			^{137}Cs	^{226}Ra
17 April 1976[b]	10.0	-	76±3	3.8±0.3
	2.77	M	53±3	17.0±0.6
	2.50	M	51±3	2.6±0.3
	3.00	M	69±3	1.4±0.2
	2.45	M	85±5	60.2±1.2
	3.40	F	68±3	<0.2
	3.18	F	62±3	2.5±0.2
	3.81	F	62±5	44.7±0.9
	3.00	F	65±4	0.4±0.1
	0.36	F	44±6	71.5±2.5
13 April 1977[c]	3.44	F	43±4	-
	2.14	F	63±9	-
	1.92	F	66±8	-
	1.10	F	44±4	-
	0.67	F	48±8	-
	0.65	M	47±5	-
	0.64	M	57±6	-

a. Information from Reference (13).
b. Analyses performed on a homogenized 300 to 400 g sample of posterior section of fish.
c. Analyses performed on homogenized whole fish.

7 SIGNIFICANCE OF MONITORING DATA

LAKE SUPERIOR

No data were obtained for Lake Superior in 1977.

LAKE MICHIGAN

The surveillance data collected at source control areas in Lake Michigan (Tables 11 and 12) show that effluents from nuclear generating stations are under control; at no time was the proposed 1 mrem objective exceeded. The average ^{3}H concentration of 330 pCi/L is similar to the 1976 value of 350 pCi/L; thus, the fallout ^{3}H level has remained essentially constant. The ^{90}Sr values for drinking water (Table 9) again are due to fallout; the average, 1.1 pCi/L, is slightly higher than the last reported value of 0.825 pCi/L in 1973. The difference can probably be attributed to measurement error, although some atmospheric testing of nuclear weapons has taken place in the intervening period, and this may have contributed ^{90}Sr to the lake. Using the conversion factor from Table 3, this level of ^{90}Sr produces a radiological dose commitment (TED_{50}) of 0.09 mrem to the whole body of an individual drinking Lake Michigan water during 1977. This is much lower than the value of 0.5 mrem given in the 1976 Appendix D for the lower ^{90}Sr value and reflects the diminution in TED_{50} to the whole body for all radionuclides, except ^{3}H and the cesium isotopes, brought about by the changes in the ICRP's recommendations.

LAKE HURON, GEORGIAN BAY, AND THE NORTH CHANNEL

Only one sample from the open waters of Lake Huron was analyzed for 1977 (Table 10). Values for ^{137}Cs and ^{125}Sb are somewhat higher than values for 1976. The values are also in reasonable agreement with data collected at two drinking water intakes in Lake Huron (Table 9). The average ^{90}Sr value of 0.72 pCi/L is similar to the value of 0.73 pCi/L reported for 1976; the 1977 value provides an annual TED_{50} of 0.06 mrem, again lower than that calculated for the previous year because of the new ICRP recommendations.

The analyses for ^{226}Ra near the mouth of the Serpent River show a slightly lower mean of 4.8 pCi/L (Table 13) than the 5.3 pCi/L reported for 1976. This average, however, is still higher than Ontario's criterion of 3 pCi/L for public surface water supplies. Using the new conversion factors, the calculated annual dose equivalent to the whole body is 2.1 mrem. Since the mouth of the Serpent River can be considered a source control area, the concentration at the 1 km boundary is the critical value. Table 14 gives a mean annual value of 3.5 pCi/L at this distance, which is equivalent to a TED_{50} of 1.5 mrem. This implies that the "Condition B" action level in the proposed refined radioactivity objective (see page 45) is operative. "Condition B" requires source investigation and corrective action if releases are not as low as reasonably achievable. As the source of the ^{226}Ra is well identified and abatement procedures are being implemented at the mines, no further action is required at the present time.

The monitoring data from the Bruce and the Douglas Point nuclear generating station source control areas (Tables 15 and 16, respectively) show no measurable releases at the two sampling times. The average ^{3}H level (<330 pCi/L) for 1977 is similar to the 1976 average and also to values reported for Lake Michigan.

LAKE ERIE

The open water data for Lake Erie (Table 10) continue to show only radioactivity from nuclear weapons testing. The mean value of 0.81 pCi/L for ^{90}Sr is slightly lower than the water intake value of 1.0 pCi/L recorded at the west end of the lake and the average 1975 value of 1.02 pCi/L. The average of 0.9 pCi/L for ^{90}Sr would result in an annual TED_{50} of 0.07 mrem to the whole body. ^{3}H levels for 1977 (Tables 9 and 17) are similar to levels in 1976.

LAKE ONTARIO

The ^{137}Cs concentration in the open waters of Lake Ontario in 1977 (Table 10) was essentially the same as in 1976. The average value of 0.023 pCi/L is lower than the average of 0.057 pCi/L for the three water intakes near the Pickering nuclear generating station (Table 9), just as it was in 1976. It is unlikely that the higher value is due to the influence of the nuclear power station since ^{134}Cs was not reported as present in the water intake samples. This radioisotope is not present in fallout but invariably is in reactor wastes.

The average concentration of ^{90}Sr in the open water is 0.93 pCi/L; this is in excellent agreement with the average value of 0.94 pCi/L reported for water intakes. This average is slightly higher than the 1976 average (0.83 pCi/L) reported for the same water intakes. The annual TED_{50} to the whole body from drinking Lake Ontario water during 1977, based on the ^{90}Sr conversion factor, is 0.07 mrem.

Although the waters of Port Hope Harbour, which receive wastes from the Eldorado Nuclear Ltd. uranium refinery, did not exceed Ontario's criterion of 3 pCi/L for ^{226}Ra during 1976, this was not the case in 1977 when three samples showed levels of 4 pCi/L (Table 18). However, the annual average for all samples is 2 pCi/L, which would produce an annual TED_{50} of 0.86 mrem to the whole body. When the contribution to the whole body dose from the ^{90}Sr of 0.07 mrem is included, the total TED_{50} becomes 0.93 mrem, which is still lower than the refined objective of 1 mrem.

The data for ^{226}Ra in Lake Ontario outside Port Hope Harbour and off the Port Granby and Welcome waste management sites for the refinery (Table 18) show levels equal to or less than the detection limit of 1 pCi/L. The more precise measurements off Port Granby (Table 19) show in fact that the ambient lake level of about 0.03 pCi/L is reached within 150 metres of the shoreline.

^{3}H was the only radionuclide detected in the vicinity of the Pickering nuclear generating station above the detection limit of the analytical method (Table 20). The highest value of 2,060 pCi/L, had it been maintained for a year, would have produced a TED_{50} of only 0.13 mrem to the whole body.

The ^{226}Ra content of fish collected in 1976 is reported in Table 22; ^{137}Cs data were reported in the 1976 Appendix D and are presented again for comparison. The ^{137}Cs values were spread over a narrow range, but the ^{226}Ra values vary from <0.2 to 71.5 pCi/kg and show no correlation with the original weight of the fish. Assuming that most of the ^{226}Ra is retained in the bones, consistent values should still be produced because the ratio of bone to tissue is reasonably constant. The same species of fish collected at the same location in 1977 show a similar range of ^{137}Cs levels with an average of 52 pCi/kg compared with 64 pCi/kg for 1976.

Analyses of fish collected near the Ginna and Nine Mile Point nuclear generating stations average 59 pCi/kg for ^{137}Cs (Table 21). The appearance of ^{134}Cs at just above the detection limit in one of the Ginna fish suggests that some of the bioaccumulated cesium may have come from the nuclear station effluent.

8 MANAGEMENT OF HIGH-LEVEL RADIOACTIVE WASTE IN THE GREAT LAKES BASIN

Storage and future disposal of irradiated nuclear fuel and fuel reprocessing wastes from the expanding nuclear power program could affect Great Lakes water quality. The subject is currently a source of public debate and has been cited by many as a major area of concern. Neither the United States nor the Canadian Government has enunciated an official policy regarding management of these wastes. The Radioactivity Subcommittee has reviewed the current status of the problem in both countries.

CANADA

In Ontario, where the majority of Canadian nuclear power development has taken place, there are currently about 1,500 tonnes of irradiated fuel stored in water-filled tanks on the sites of the power plants. Spent fuel is now being produced at a rate of about 800 tonnes per year. Two reports on future management of this spent fuel were recently published. *The Management of Canada's Nuclear Wastes* (16) by A. M. Aikin, J. M. Harrison, and F. K. Hare, usually called the "Hare Report", was commissioned by the Department of Energy, Mines and Resources; *The Disposal of Ontario's Used Nuclear Fuel* (17) by R. J. Uffen, was commissioned by Ontario Hydro. The Hare Report concluded that there are good prospects for the safe, permanent disposal of highly radioactive wastes and there is no need to delay the nuclear power development program. Uffen's report, however, echoed the recommendation of Sir Brian Flowers in *Nuclear Power and the Environment* (18), that there should be no commitment to a large program of nuclear power development, i.e. development greater than 20,000 megawatts in Ontario, until a safe disposal method has been demonstrated. Both agreed that a major research program should be undertaken immediately by the Canadian Government to develop the disposal method involving deep burial of vitrified wastes in geological formations. The Hare Report recommended test disposals of immobilized spent fuel at one site in Ontario by 1990. It concluded that selection of a site outside the Great Lakes Basin is not an advantage since the paramount consideration must be a site that will not fail.

Following the recommendations of the Hare Report, Canada and Ontario jointly announced on June 5, 1978 a program to develop a permanent, safe disposal system for radioactive waste materials (25). The federal government will undertake research and development in the immobilization and disposal of radioactive wastes in underground repositories, and the province will study problems with interim storage and transportation.

The research and development will determine whether permanent disposal of radioactive waste in deep underground repositories in intrusive igneous rock is safe, secure, and desirable. Geological field studies will begin in 1978 to evaluate the effectiveness of barriers to prevent the release of radioactivity to the environment; about 1,500 geological formations in Ontario will be classified as to suitability.

Ontario has made no commitment to reprocessing or to depositing waste from other provinces in Ontario. The tentative program schedule is:

1978-1980 - Geological survey work, experimental drilling, and accelerated research and development

1981-1983 - Site selection for demonstration repository

1983 - Site acquisition

1985-2000 - Disposal demonstration

2000 and Beyond - Full scale facilities operational

Federal-provincial coördination will involve a committee representing Atomic Energy of Canada Limited, Ontario Hydro, Ontario Ministry of Energy, and the federal Department of Energy, Mines and Resources.

UNITED STATES

In New York State, the West Valley site of Nuclear Fuel Services currently stores about 2.3 million litres of high-level waste. Even though no further fuel reprocessing is planned, this presents a major disposal problem. B. L. Cohen, in *The Disposal of Radioactive Wastes from Fission Reactors* (19), recommends incorporation of these wastes into glass and deep burial after a ten-year cooling period. As yet, no decision has been made by the licencing authority, the Nuclear Regulatory Commission, as to what future action should be taken. Congress has required the Department of Energy (DOE) to conduct a study of possible disposal methods for this waste and future use of the site. The study should be completed by the end of 1978.

Preliminary explorations by the Energy Research and Development Agency (ERDA) for a site for a high-level waste disposal facility near Rogers City, Michigan, caused that state to enact Act 113, P.A. 1978 (formerly Senate Bill 144) to prohibit any disposal of high-level radioactive waste within the state. Both EPA and ERDA are continuing studies on methods and criteria for high-level waste disposal, but plans for a high-level waste facility have been postponed from 1985 until 1990 or later. DOE has stated it will not initiate any program for such a depository without state involvement. EPA has prepared a background report on environmental protection criteria for radioactive waste disposal as a result of two workshops on the subject (23).

9 CONCLUSIONS

The levels of radionuclides in Lakes Michigan, Huron, Erie, and Ontario were monitored during 1977 in the open lakes, in nearshore waters, and at municipal water intakes. Essentially all of the radioactivity detected in the Great Lakes comes from nuclear weapons testing fallout, except for ^{226}Ra which, though it occurs naturally, is occasionally enhanced by uranium mining and refining operations. Concentrations of radionuclides measured in 1977 remain low and are similar to those found in 1976. The only detectable effects of nuclear power plant operations were occasional transient increases in ^{3}H and ^{137}Cs levels near the discharges of two nuclear power stations. These increased levels were only a fraction of the 1 mrem proposed Agreement objective. Fish in Lake Ontario continue to show levels of ^{137}Cs which correlate with levels in the water, although ^{226}Ra concentrations are quite variable. The average concentration of ^{226}Ra at the mouth of the Serpent River, which drains the Elliot Lake uranium mining area, decreased slightly from 1976. The Serpent River is a problem area because the ^{226}Ra level of 4.8 pCi/L exceeds Ontario's criterion of 3 pCi/L. The annual average levels of ^{226}Ra in Port Hope Harbour, which receives waste from a uranium refinery, is $\sim$2 pCi/L; this level would result in an annual radiological dose commitment to an individual drinking the water of 0.86 mrem. Added to this would be another 0.07 mrem from the ^{90}Sr, giving a total of 0.93 mrem, which is less than the proposed Agreement objective.

The major contributor to radiological dose commitment in Great Lakes water is ^{90}Sr. Since strontium is a conservative element, it is only lost by radioactive decay (half life = 30 years) and by flushing. Although weapons testing has been continued by China, the addition to the northern hemisphere's inventory of ^{90}Sr from the 1976-1978 tests will have been minor. This is borne out by the 1977 surveillance data for the Great Lakes which show negligible change from 1976.

A major change in the International Commission on Radiological Protection's recommendations for the calculation of dose was published in 1977. Although the concentration of ^{90}Sr in the waters of the Great Lakes was about the same in 1976 and 1977, the calculated dose decreased drastically for 1977 because of the changes in the ICRP's recommendations (see Chapter 3). The value for 1976 averaged 0.4 mrem for all the lakes (1), and the average for 1977 is 0.07 mrem. The background level of radiological dose from Great Lakes water is only a small fraction of the proposed Agreement objective.

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APPENDIX I

PROPOSED REFINED RADIOACTIVITY OBJECTIVE FOR THE GREAT LAKES WATER QUALITY AGREEMENT[24]

SUMMARY

This document represents the joint recommendations of U.S. and Canadian advisory groups on a radioactivity objective to preserve the water quality of the Great Lakes. The objective is in terms of a dose equivalent to ICRP Reference Man from a standard annual intake of the Great Lakes water. The recommended objective for the general water quality in the Great Lakes is that level of radioactivity which results in a whole body dose equivalent not exceeding one millirem. Release of radioactive materials shall be as low as reasonably achievable and controlled by specified actions at defined levels.

REFINED RADIOACTIVITY OBJECTIVE

The Canada-United States Great Lakes Water Quality Agreement specified radioactivity as a constituent of water for which there should be an agreed Water Quality Objective. The relevant statements in the Agreement are as follows:

Annex 1, Section 1(h) states: "Radioactivity should be kept to the lowest practicable level. In any event, discharges should be controlled to the extent necessary to prevent harmful effects on health."

Annex 1, Section 7(b) further states: "for radioactivity, the objective shall be considered in the light of the recommendations of the International Commission on Radiation [sic] Protection."

Further, this section requires the parties to consult "for the purpose of considering a refined objective for radioactivity."

Subsequently, advisory groups were formed in Canada and in the United States to consider the technical aspects involved in developing such a "refined objective". The present report was developed following extensive consultation between the two groups.

To restore and enhance water quality in the Great Lakes System, as called for in the Agreement, it is necessary to limit the quantity of radioactive materials introduced due to activities of the United States of America and Canada. An acceptable quality for water in the system can best be maintained by a vigorous application of appropriate control measures. These controls should be applied to radioactive effluents from point sources as well as run-off, drainage, and seepage from non-point sources, including aerial deposition.

The Radioactivity Objective for the Great Lakes Basin is based principally on three criteria:

(1) Introduction of radioactive materials into System Waters should be permitted only when it results from socially beneficial activities.

(2) The concentration of radioactivity in the System Waters and in biota should not constitute an unacceptable health risk on either a long-term or short-term basis.

(3) Since the ingestion of any amount of radioactivity may involve some risk, additional controls should be instituted until their cost is incommensurate with any further reduction in potential health risks.

In keeping with these criteria, several recommendations have been agreed to. These recommendations refer to an Ambient Water Quality Objective, the control of radioactive releases, a defined hierarchy of Action Levels and the surveillance of Lake Waters. None of the proposed levels, including particularly the lowest, should be interpreted as necessarily defining an acceptable dose to the population using System Waters. The acceptability of any dose level depends on whether the three criteria given above are being met in a responsible manner. It is further proposed that these objectives be reviewed at least every five years to consider any necessary changes and to determine if they continue to reflect "as low as reasonably achievable".

AMBIENT WATER QUALITY

It is necessary to specify an ambient water quality level for the Lakes as a whole so that contributions from all sources including aerial deposition are taken into account. This water quality level is expressed in terms of the total equivalent dose to ICRP Reference Man integrated over 50 years, (TED_{50}). It is proposed that water quality outside of any Source Control Area, as defined herein, shall not result in a TED_{50} greater than one millirem to the whole body from daily ingestion of 2.2 liters of Lake water for one year. Therefore, even for lifetime (50 years) ingestion, the annual dose rate will not exceed 1 millirem per year. The total equivalent dose to a single organ or tissue shall be in proportion to the dose limit recommended by the ICRP for that tissue. Because levels in the lakes may fluctuate as a result of uncontrollable releases, such as fallout from weapon testing, it is further recommended that the one millirem value be reviewed at least every five years to ensure that the contribution from these uncontrollable releases does not constitute an unreasonable proportion of the dose.

CONTROL OF RELEASE OF RADIOACTIVE MATERIALS

Dumping of radioactive wastes or other radioactive material into waters of the Great Lakes system is prohibited. Dumping is defined as any deliberate disposal of packaged or unpackaged wastes or other matter from vessels, platforms or other man-made structures into the System Waters, but dumping does not include the release of effluents that are permitted by the responsible regulatory bodies.

Both the concentrations and quantities of radioactive materials released into the Great Lakes System shall be controlled to the extent necessary to protect public health and the environment. Releases of radioactive materials from each operation or type of operation should be controlled so as to conform with the ICRP recommendation that "all doses be kept as low as is reasonably achievable economic and social considerations being taken into account". (ICRP Pub. 22 1973).

Effluents should be controlled by the regulatory bodies having jurisdiction, taking into account the cost of further reductions, the efficacy of available additional control measures, and the significance of the potential reduction in public health risk associated with further discharge limitations.

A graded scale of actions for each identifiable source shall be implemented based on annual average measurements of the TED_{50} in water monitored at the periphery of each source control area, in accordance with the action conditions given below in Table I.

TABLE I - ACTION CONDITIONS

CONDITION	ACTION REQUIRED	ACTION LEVEL TED_{50} (mrem)
A	Periodic confirmatory monitoring	Less than 1
B	Source investigation and corrective action if releases are not as low as reasonably achievable	Between 1 and 5
C	Corrective action by responsible regulatory authorities	In excess of 5

Action levels are to be calculated in accordance with the dose models used by the ICRP.

The annual average shall be based on the average value of at least 4 measurements in a year. Since there is a relatively high probability of sampling error, measurements should be verified before action is taken.

When the concentrations of radionuclides in the water correspond to Condition A, no corrective action is indicated. However, periodic monitoring is required to confirm that the condition does not change.

When the concentrations of radionuclides in the water correspond to Condition B, an investigation must be conducted to identify the source and the cause. If this investigation demonstrates that releases are as low as reasonably achievable no further action is necessary; otherwise, corrective action shall be taken.

Concentrations of radionuclides in the water corresponding to Condition C probably reflect a failure of effluent controls and are unacceptable on a continuing basis. The responsible regulatory authorities shall determine appropriate corrective actions to minimize the public health risk.

SURVEILLANCE

Adequate periodic monitoring of System Waters, sediment, and the appropriate food organisms contained therein should be provided for those radionuclides likely to the present in measurable concentrations. Such monitoring should be conducted under the direction of the responsible Federal, State, and Provincial jurisdictions and reported to the International Joint Commission. The nuclides and food organisms investigated, and sampling locations and frequency should take into account the known effluent sources and particular nuclides released.

The monitoring reports should include calculations of the TED_{50} to ICRP Reference Man from standard annual intake of the water since this is the parameter to be used in determining the applicable Action Condition. At present it is not necessary to determine explicity the dose equivalents due to the intake of food harvested from the Lakes as they are relatively insignificant.

DEFINITIONS

1. Total Equivalent Dose (TED_{50}): For the purpose of this report, the total equivalent dose to a particular organ, tissue or the whole body is the cumulated dose equivalent over 50 years resulting from the daily ingestion of 2.2 liters of lake water for one year.

$$TED_{50} = \Sigma_i \quad D_{50i} \; Q_i \; N_i \qquad \text{rem}$$

where:

D_{50} = total absorbed dose integrated over a period of 50 years after intake of the radionuclide "i"

Q_i = quality factor

N_i = product of all other modifying factors

ICRP report No. 10 [21] lists the dosimetric data, including the TED_{50}, for a number of radionuclides.

2. Reference Man: For the purpose of this report, Reference Man refers to the definitions and parameters for adult males outlined in ICRP Report 23 [22].

3. Source Control Area: It is proposed that the "source control area" be defined as follows: "The source control area shall be bounded by a distance of 1 km radius from the point of release or, in those cases where the release point is to a narrow channel or river, the boundary shall be a point 1 km downstream from the source."

It is further proposed that the operator of a facility can request a larger source control area subject to the approval of the regulatory authorities and similarly these authorities may require a more restrictive area from an operator.

4. Ambient Water: The water in the Great Lakes System outside the source control areas.

APPENDIX II

PROPOSED RADIOACTIVITY SURVEILLANCE PROGRAM FOR THE GREAT LAKES

PROPOSED AGREEMENT OBJECTIVE

The motive for the establishment of a radiological surveillance program for the Great Lakes and their tributaries is the evaluation of the quality of those waters against the proposed Agreement objective which proposes a total equivalent dose (TED_{50}) of no more than 1-5 mrem to the whole body per year as a result of the daily ingestion of 2.2 litres of lake water by a standard man (see Appendix I). Dose equivalent to a single organ or tissue shall be in proportion to the "implied" dose limit recommended by the International Commission on Radiological Protection (ICRP) for that tissue (2). For stochastic effects, the ICRP dose limitation is based on the principle that the risk should be equal whether the whole body is irradiated uniformly or non-uniformly. See Chapter 3 for additional discussion.

Associated with the proposed Agreement objective is a procedure for controlling point source inputs of radioactivity to the Great Lakes. A source control area (SCA) is that area within a one kilometre radius of the discharge from a designated source. Monitoring of radionuclide concentrations in water samples from the periphery of the SCA provides TED_{50} measurements that will require defined action conditions depending on whether the level is (A) less than 1 mrem, (B) between 1 and 5 mrem, and (C) in excess of 5 mrem.

BASIS FOR SURVEILLANCE

The primary purposes for radioactivity surveillance are to assess compliance with the proposed Agreement objective through calculation of radiological dose, and to determine trends. The Radioactivity Subcommittee (RSC) has identified five general areas for radiological surveillance. By order of priority, these are: SCA's, ambient waters, potable water supplies, biota, and sediments. The first two are essential for assessing compliance. The basis for each type of program is discussed below.

SOURCE CONTROL AREA

Although the proposed Agreement objective does not allude to contributions from controlled sources, it continues to be prudent to include source monitoring in the surveillance scheme to determine what action level regime is extant at the SCA periphery. Adequate assessment of the contribution from controlled sources will necessitate sampling more frequently than the minimum of four annual measurements indicated in the proposed Agreement objective.

In light of the lake inventory of fission products from atmospheric weapons testing, analytic schemes must be selected which accurately assign observed activities to the proper source. A useful technique in that area is the development of $^{89}Sr/^{90}Sr$ and $^{134}Cs/^{137}Cs$ activity ratios, which are significantly greater in the effluents of thermal fission facilities than in older products of weapons testing.

As a minimum, waters at or near the periphery of the SCA of the facility outfall should be sampled at least monthly and composited quarterly for analysis. Grab sampling will have to be acceptable in that most desirable locations are seldom attended on a continuing basis.

In the case where the controllable source is located on a tributary, the stream should be sampled at a distance of 1 to 5 km downstream of the outfall. Sampling should be from the bank of the stream where the plume is likely to be observed. This sample is to be accompanied by a grab sample of water taken from a suitable upstream location on the same day.

In the case where the controllable source is located on the shore of a lake, the water should be sampled 1 metre below the surface at two points near the shore line and at least two points in the lake proper at loci 1 km from the source outfall. The selection of sampling points should allow for the sampling of at least one point likely to be in the plume at the time of sampling. Local considerations may result in modifications to this scheme. For example, two discharges located close to each other may result in the same stations being used to monitor both. Also, for example, a public water intake, where the purpose of monitoring is different (see below), may also be designated a SCA station.

AMBIENT WATERS

These samples provide for the assessment of ambient lake waters, namely those waters well outside the SCA. Sampling of the waters of the open lakes is included in this consideration.

No organization is presently engaged in the routine year-round radiological surveillance of open lake water. Studies are done, however, on a periodic basis by several organizations in the interest of applied research.

These surveillance efforts are certainly of considerable merit. Their results must enter into the evaluation of the prevailing quality of lake water. These data, however, are not applicable to the assessment of controlled source conditions, nor are they indicative of human uptake.

The organizations which conduct these studies should make the results available routinely to the IJC along with their discussion of the results.

As a minimum radiological surveillance program for each lake, samples should be collected at least annually from at least 3-5 stations at one or more depths. The stations should be spread across the lake and be at least 15 km offshore. The sample collection program is to be developed in conjunction with the Surveillance Subcommiteee.

PUBLIC WATER SUPPLIES

Monthly paired composites of raw and finished domestic drinking water should be considered. Finished drinking water is the only point at which uptake by man can truly be observed. Further, finished drinking water is sampled frequently and routinely at the treatment plant, a situation lending itself to compositing. The composite sampling of raw water at domestic water treatment plants provides a companion estimation of lake water conditions as directed to man.

The sampling of the U.S. public water supplies on the Great Lakes under this proposed radioactivity surveillance program may be integrated with the radiological monitoring requirements under the U.S. Safe Drinking Water Act.

FISHERY

Food (primarily fish) harvested from the lakes and consumed by man is another pathway of radioactivity to man. The level of radioactivity in fish is also an indicator of the level in water. The radionuclides sought include ^{137}Cs, ^{134}Cs, ^{125}Sb, and ^{90}Sr. The sample collection and preparation program is to be developed in conjunction with the Fish Contaminant Work Group of the Surveillance Subcommittee.

OPEN WATERS

Homogenized samples of whole fish collected annually at 2-4 stations in the open waters of each lake should be analyzed to determine radioactivity levels and trends. Analyses should be performed on a top-of-the-line predator (such as lake trout or walleye) and a bottom feeder. The fish should be from the same location(s) each year.

NEARSHORE WATERS

Non-migratory fish and other biota should be collected from the vicinity of selected nuclear power plant outfalls to determine the presence of radionuclides from this type of source. The analyses should be performed on the edible portion of fish. At least two U.S. and two Canadian dischargers should be sampled at least annually.

SEDIMENT

The sediment generally acts as a sink for materials in the water column. For radioactivity assessment, at least one core sample (at least the top 10 cm) should be collected annually from the major depositional sub-basins of each lake and analyzed for ^{137}Cs and ^{125}Sb. The sample collection program is to be developed in conjunction with the Surveillance Subcommittee.

PARAMETERS

The radionuclides sought in the samples collected for radiological analysis depend on the type of nuclear operation being monitored. Table 4 lists the longer-lived radionuclides which might be expected to be released from different kinds of nuclear operations and those that occur from fallout from nuclear weapons testing.

DETAILED SURVEILLANCE PLAN

The detailed radiological surveillance plan for the Great Lakes is given by lake in Tables 23-27. Information given for each type of program includes the responsible jurisdiction, sites, parameters, number of stations, and the sample analysis frequency. Figures 2-6 locate the sampling stations and/or sites. These plans, as well as the other aspects of the overall program, are to be considered dynamic and will be updated as further details are developed.

QUALITY CONTROL

In applying environmental data to estimating dose equivalent to a postulated individual, the radiation protection specialist is generally prone to accepting the data as being flawless and above critical observation. The public at large, including non-specialists, is particularly vulnerable to the acceptance of these improper conclusions. In that the proposed Agreement objective is subject to the interpretation of data generated by a number of agencies under the jurisdiction of local, provincial, state, and federal government, it is crucial to the long-term durability of the Agreement that each datum, regardless of analyst, be compatible and traceable to a recognized authority in radioanalytic standards. Therefore, the jurisdictions contributing data for the radiological assessment of the Great Lakes have all agreed to participate in the U.S. Environmental Protection Agency's ongoing quality assurance program. Thus, each laboratory supplying data for demonstrating compliance with the proposed Agreement objective will have demonstrated its capability to produce reliable data to the required analytic sensitivity. The concentrations for each radionuclide which must be detectable are given in Table 5. The error associated with a measurement at this lower limit of detection for each radionuclide will be determined.

COSTS

Three costs are presented by jurisdiction in Table 28: present expenditures, costs (primarily capital) to upgrade to meet the objectives of Great Lakes surveillance, and the cost to operate the upgraded program.

The purpose of radiological surveillance by agencies is often different from the surveillance required under the Agreement. 1976 Appendix D (1) summarizes (page 10, Table 4) present surveillance activities by each jurisdiction but concludes that although the water sampling part of the program is well established, the specific radionuclide analyses required are not done. Therefore, the RSC's ability to completely assess the radiological dose to an individual drinking lake water or consuming lake fish cannot be done. Therefore, the members of the RSC have estimated the cost for each jurisdiction to upgrade to meet the objectives of Great Lakes radiological surveillance and then the cost to operate the upgraded program.

Research or intensive programs are designed to determine the extent or the potential presence of radioactivity at a given location. An example is radionuclides from medical sources possibly being present at sewage treatment plant outfalls. Such programs have a finite time frame. Research costs have not been estimated.

TABLE 23

PROPOSED RADIOACTIVITY SURVEILLANCE PROGRAM FOR LAKE SUPERIOR 1979 AND BEYOND

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Water Intake	Minnesota	Duluth	1	^{3}H, ^{90}Sr, gross α, gross β	4	Quarterly samples, composited annually	4	Finished water
		Cloquet, Two Harbors, Beaver Bay, Silver Bay, Grand Marais	5 (1 at each site)	gross α. If > 5 pCi/L, then ^{226}Ra. If [^{226}Ra] > 3 pCi/L, then ^{228}Ra.	1	Quarterly samples, composited annually	5	Finished water
Open Water	U.S. EPA	In open water; actual site is variable	2	^{3}H, ^{90}Sr, ^{226}Ra, gross α, gross β	5	Quarterly	40	
	Canada DFE	In open water; actual site is variable	3; 2 depths per station	^{3}H, ^{90}Sr, γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	3	Annually	18	
Biota	Canada DFE	In open water; actual site is variable		γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	1	Three times per year	3	Whole fish
Sediment	Canada DFE	In open water; actual site is variable	2 (1 in each sub-basin)	^{137}Cs, ^{125}Sb, other γ-emitters	2	Irregular - preferably annually. Core sample.	4	

[a] "γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Figure 2

SAMPLE COLLECTION LOCATIONS FOR RADIOACTIVITY SURVEILLANCE IN LAKE SUPERIOR

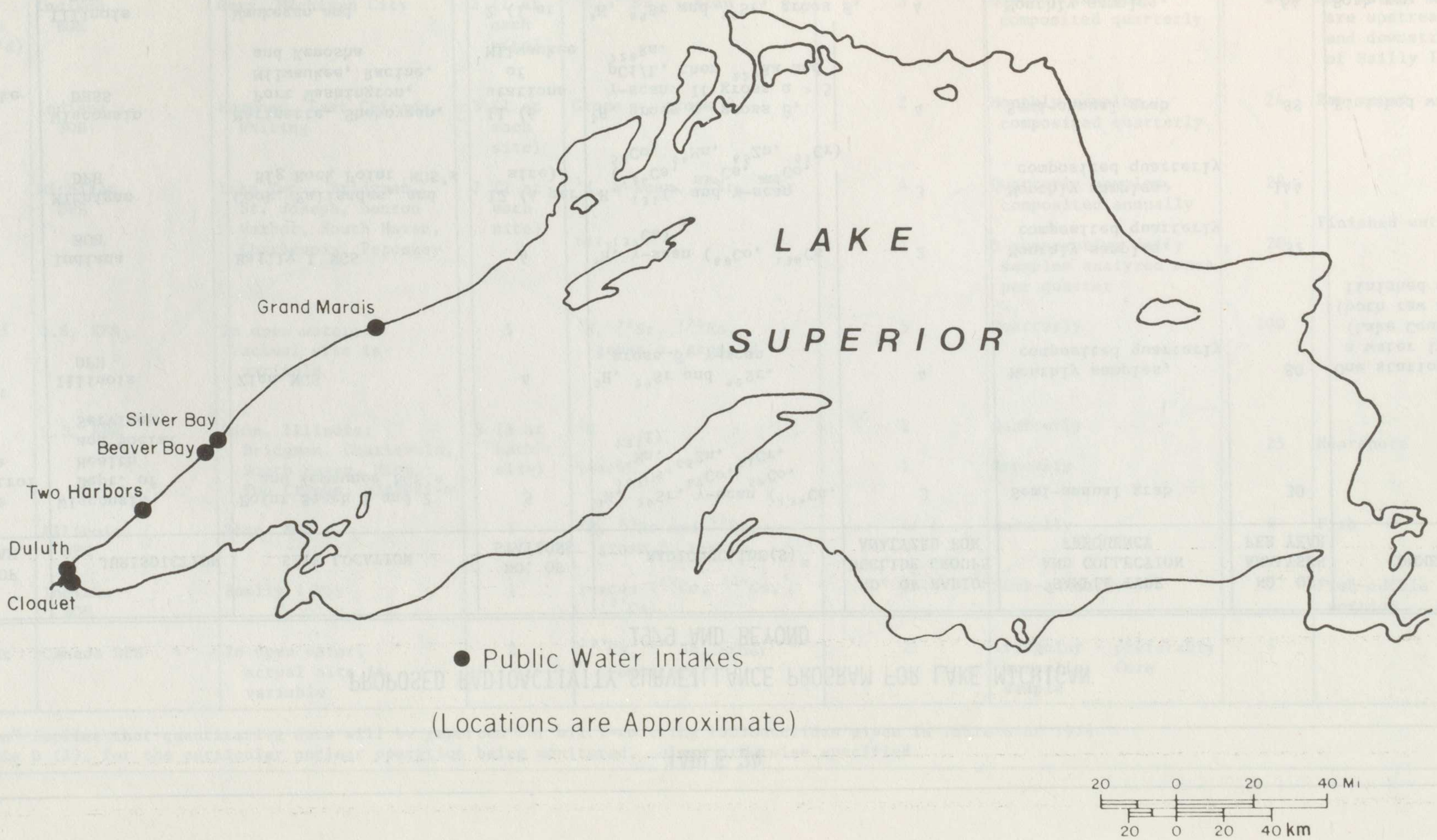


TABLE 24

PROPOSED RADIOACTIVITY SURVEILLANCE PROGRAM FOR LAKE MICHIGAN 1979 AND BEYOND

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S) [a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Source Control Area	Wisconsin Dept. of Health and Social Services	Point Beach 1 and 2 and Kewaunee NGS's	5	^{3}H, ^{90}Sr, γ-scan (^{134}Cs, ^{137}Cs, ^{60}Co, ^{58}Co, ^{54}Mn, ^{65}Zn, ^{51}Cr, ^{131}I)	3	Semi-annual grab	30	
	Illinois DPH	Zion NGS	4	^{3}H, ^{89}Sr and ^{90}Sr, gross β, γ-scan	4	Monthly samples, composited quarterly	80	One station is a water intake (Lake County) (both raw and finished water)
	Indiana BOH	Bailly I NGS	4	^{3}H, γ-scan (^{60}Co, ^{134}Cs, ^{137}Cs)	2	Monthly samples, composited quarterly	32	
	Michigan DPH	Cook, Palisades, and Big Rock Point NGS's	12 (4 per site)	^{3}H, ^{131}I, and γ-scan (^{134}Cs, ^{137}Cs, ^{60}Co, ^{58}Co, ^{54}Mn, ^{65}Zn, ^{51}Cr)	3	Monthly samples, composited quarterly	144	
Water Intake	Wisconsin DHSS	Marinette, Sheboygan, Port Washington, Milwaukee, Racine, and Kenosha	11 (6 stations of Milwaukee	^{3}H, gross α, gross β, γ-scan. If gross α > 5 pCi/L, then ^{226}Ra and ^{228}Ra.	4	Semi-annual grab	88	Finished water
	Illinois DPH	Waukegan and Lake County	2 (1 at each site)	^{3}H, ^{89}Sr and ^{90}Sr, gross β, γ-scan.	4	Monthly samples, composited quarterly	64	Both raw and finished water. See also SCA program above.

[a] "γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Table 24 cont'd.

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIO-NUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Water Intake (cont'd)	Indiana BOH	Gary, Michigan City	2 (1 at each site)	^{3}H, ^{90}Sr, γ-scan	3	Monthly samples, composited quarterly	24	Raw water. Sites are upstream and downstream of Bailly I NGS
	Indiana BOH	Hammond, East Chicago, Whiting	3 (1 at each site)	Gross α, gross β	2	Monthly samples, composited quarterly	24	Raw water
	Michigan DPH	Lake Twp., Bridgman, St. Joseph, Benton Harbor, South Haven, Charlevoix, Petoskey	7 (1 at each site)	^{3}H, γ-scan, ^{89}Sr, ^{90}Sr	4	Quarterly samples, composited annually	28	Finished water
				^{131}I	1	5 consecutive daily samples analyzed once per quarter	28	
Open and Near-shore waters	U.S. EPA	In open water; actual site is variable	5	^{3}H, ^{90}Sr, ^{226}Ra, gross α, gross β	5	Quarterly	100	
	U.S. EPA	Zion, Illinois; Bridgman, Charlevoix, South Haven, Mich.; Two Creeks, Wisconsin	5 (1 at each site)	^{3}H	1	Quarterly	25	Nearshore
				γ-scan	1	Annually		
Biota	Illinois DPH	Zion NGS	1	^{3}H, ^{89}Sr and ^{90}Sr, gross β, γ-scan	4	Annually	4	Fish
	Indiana BOH	Bailly I NGS	1	γ-scan (^{60}Co, ^{134}Cs, ^{137}Cs)	1	Semi-annually	2	Fish-edible portion.
Sediment	Canada DFE	In open water; actual site is variable	2	^{137}Cs, ^{125}Sb, other γ-emitters	2	Irregular - preferably annually. Core sample	4	

[a]"γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Figure 3

SAMPLE COLLECTION LOCATIONS FOR RADIOACTIVITY SURVEILLANCE IN LAKE MICHIGAN

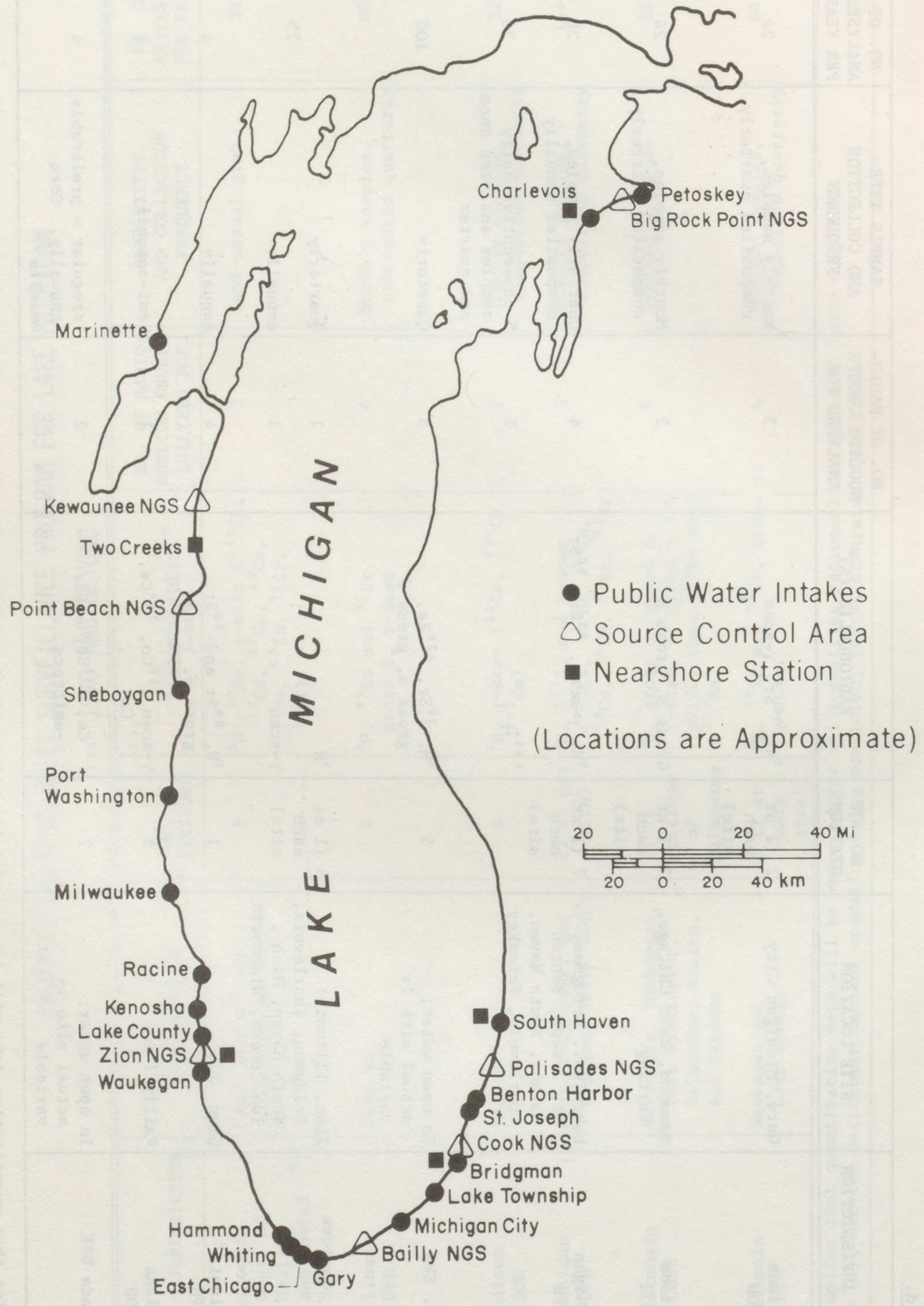


Figure 4

SAMPLE COLLECTION LOCATIONS FOR RADIOACTIVITY SURVEILLANCE IN LAKE HURON

TABLE 25

PROPOSED RADIOACTIVITY SURVEILLANCE PROGRAM FOR LAKE HURON 1979 AND BEYOND

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Source Control Area	Michigan DPH	Midland NGS	2	^{3}H, ^{131}I, γ-scan (^{134}Cs, ^{137}Cs, ^{60}Co, ^{58}Co, ^{54}Mn, ^{65}Zn, ^{51}Cr)	3	Monthly samples, composited quarterly	24	
	Ontario MOE and MOL	Bruce "A" and Douglas Point NGS's	16 (8 per site)	^{3}H and γ-scan (^{134}Cs, ^{137}Cs, ^{60}Co)	2	Monthly samples, composited quarterly	128	
	Ontario MOE and MOL	Serpent River Mouth	7	^{226}Ra, ^{228}Ra, ^{230}Th, ^{210}Pb	4	Monthly samples, composited quarterly	112	
Water Intake	Michigan DPH	Midland, Saginaw, Pinconning, Bay City	4 (1 at each site)	^{3}H, γ-scan, ^{89}Sr, ^{90}Sr	4	Quarterly samples, composited annually	16	Finished water
				^{131}I	1	5 consecutive daily samples analyzed once per quarter	16	
	Canada NH&W	Serpent River and Harbour	3	^{226}Ra, ^{210}Pb, U	3	Monthly composites of daily samples	108	
	Canada NH&W	Kincardine, Port Elgin	2 (1 at each site)	^{90}Sr, ^{137}Cs	2	Daily grabs, composited monthly	48	Raw water
	Canada NH&W	Elliot Lake	1	^{226}Ra, ^{210}Pb, U	3	Monthly grabs	36	Finished water

[a] "γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Table 25 cont'd.

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Open Water	U.S. EPA	In open water; actual site is variable	2	^{3}H, ^{90}Sr, ^{226}Ra, gross α, gross β	5	Quarterly	40	
	Canada DFE	In open water; actual site is variable	3; 2 depths per station	^{3}H, ^{90}Sr, γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	3	Annually	18	
Biota	Canada DFE	In open water; actual site is variable		γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	1	Three times per year	3	Whole fish
	Canada NH&W	Serpent River and Harbour	3	^{226}Ra, ^{210}Pb, U	3	Quarterly	36	Fish
Sediment	Canada DFE	In open water; actual site is variable	3	^{137}Cs, ^{125}Sb , other γ-emitters	2	Irregular - preferably annually. Core sample	6	

[a] "γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

TABLE 26

PROPOSED RADIOACTIVITY SURVEILLANCE PROGRAM FOR LAKE ERIE
1979 AND BEYOND

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Source Control Area	Michigan DPH	Fermi 2 NGS	4	^{3}H, ^{131}I, γ-scan (^{134}Cs, ^{137}Cs, ^{60}Co, ^{58}Co, ^{54}Mn, ^{65}Zn, ^{51}Cr)	3	Monthly samples, composited quarterly	48	
	Ohio DOH	Davis-Besse, Perry, and Erie NGS's	12 (4 per site)	^{3}H; gross α; ^{89}Sr and ^{90}Sr; γ-scan	4	Monthly samples, composited quarterly	192	
	New York DEC	Cattaraugus Creek	1	^{3}H, gross α, gross β	3	Monthly	36	Discharge stream for NFS
	New York DEC	Buffalo STP	1	^{3}H, ^{131}I, gross α; gross β, γ-scan	5	Monthly	60	Hospitals, etc.
Water Intake	Michigan DPH	Monroe, Flat Rock	2 (1 at each site)	^{3}H, γ-scan, ^{89}Sr, ^{90}Sr	4	Quarterly samples, composited annually	8	Finished water
				^{131}I	1	5 consecutive daily samples analyzed once per quarter	8	
	Ohio DOH	Toledo, Port Clinton, Sandusky, Huron, Lorain, Cleveland, Painesville, Ashtabula	8 (1 at each site)	^{3}H, gross β	2	Monthly	192	Raw water
				^{89}Sr & ^{90}Sr; γ-scan	2	Quarterly composites	64	
	Pennsylvania	Erie	1	^{3}H, ^{90}Sr, γ-scan	3	Monthly composited sample	36	Finished water
	New York DEC	Angola	1	^{3}H, gross α, gross β	3	Weekly	156	Finished water

[a] "γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Table 26 cont'd.

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Water Intake (cont'd.)	New York DEC	Sturgeon Point	1	^{3}H, ^{90}Sr, γ-scan	3	Monthly	36	Raw water
				^{226}Ra	1	Annual	1	
	New York DEC	Dunkirk	1	^{3}H, gross α, gross β	3	Quarterly	12	Raw water
Open and Nearshore Water	U.S. EPA	In open water; actual site is variable	5	^{3}H, ^{90}Sr, ^{226}Ra, gross α, gross β	5	Quarterly	100	
	U.S. EPA	Monroe, Mich. and Toledo, Ohio	2 (1 at each site)	^{3}H	1	Quarterly	8	Nearshore
				γ-scan	1	Annually	2	
	New York DEC	Niagara River	1	^{3}H, gross α, gross β	3	Quarterly	12	Observed data can be considered as integrated value for Lake Erie
	Canada DFE	In open water; actual site is variable	3; 2 depths per station	^{3}H, ^{90}Sr, γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	3	Annually	18	
Biota	Ohio DOH	Davis-Besse, Perry, and Erie NGS's	3 (1 per site)	^{3}H, gross β; ^{89}Sr & ^{90}Sr; γ-scan	4	Semi-annual	24	Fish
	New York DEC	Cattaraugus Creek	1	^{90}Sr, γ-scan	2	Semi-annual	8	Fish; aquatic vegetation
	Canada DFE	In open water; actual site is variable		γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	1	Three times per year	3	Whole fish
Sediment	Canada DFE	In open water; actual site is variable	3 (1 in each sub-basin)	^{137}Cs, ^{125}Sb, other γ-emitters	2	Irregular - preferably annually. Core sample.	6	

[a] "γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Figure 5

SAMPLE COLLECTION LOCATIONS FOR RADIOACTIVITY SURVEILLANCE IN LAKE ERIE

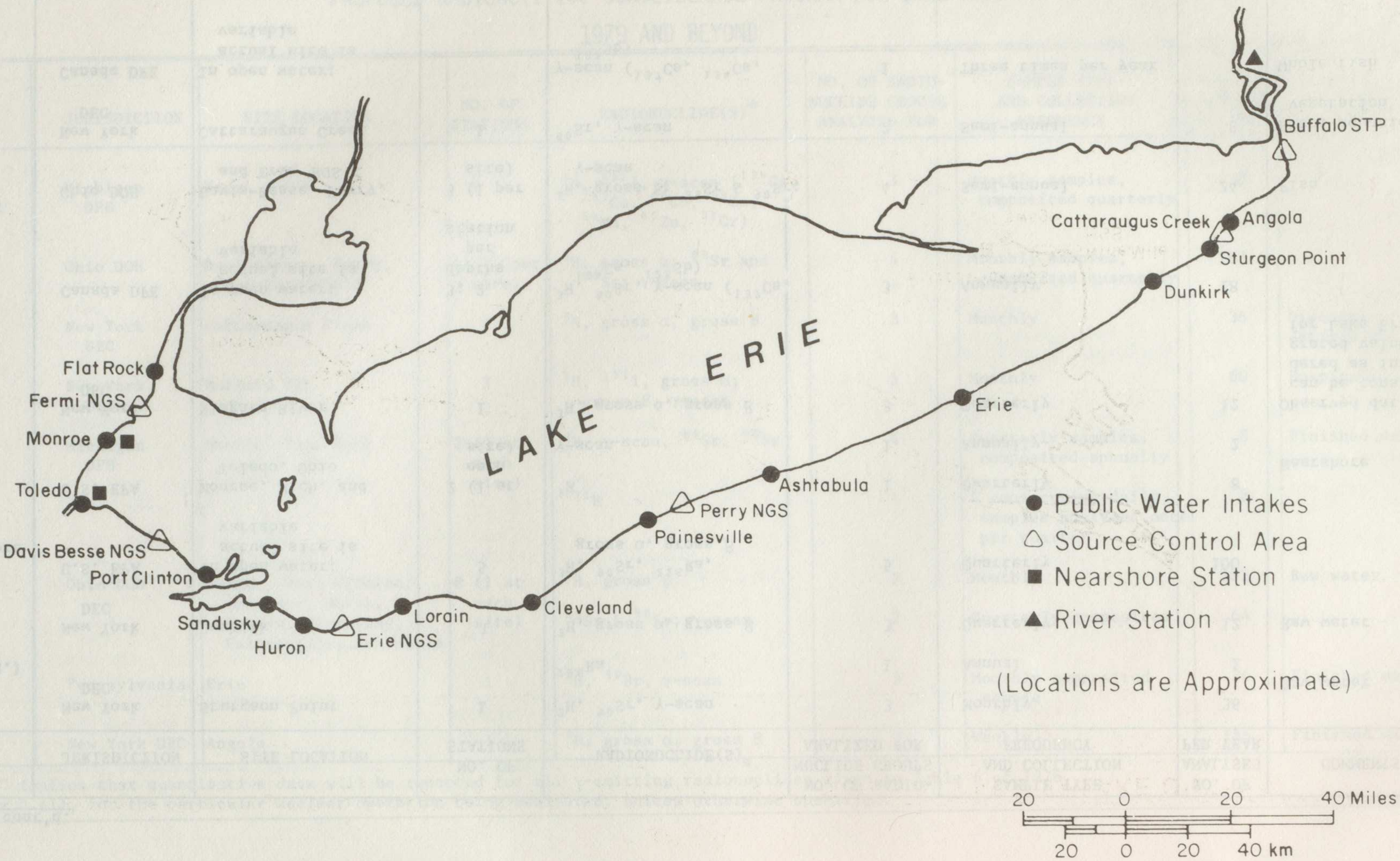
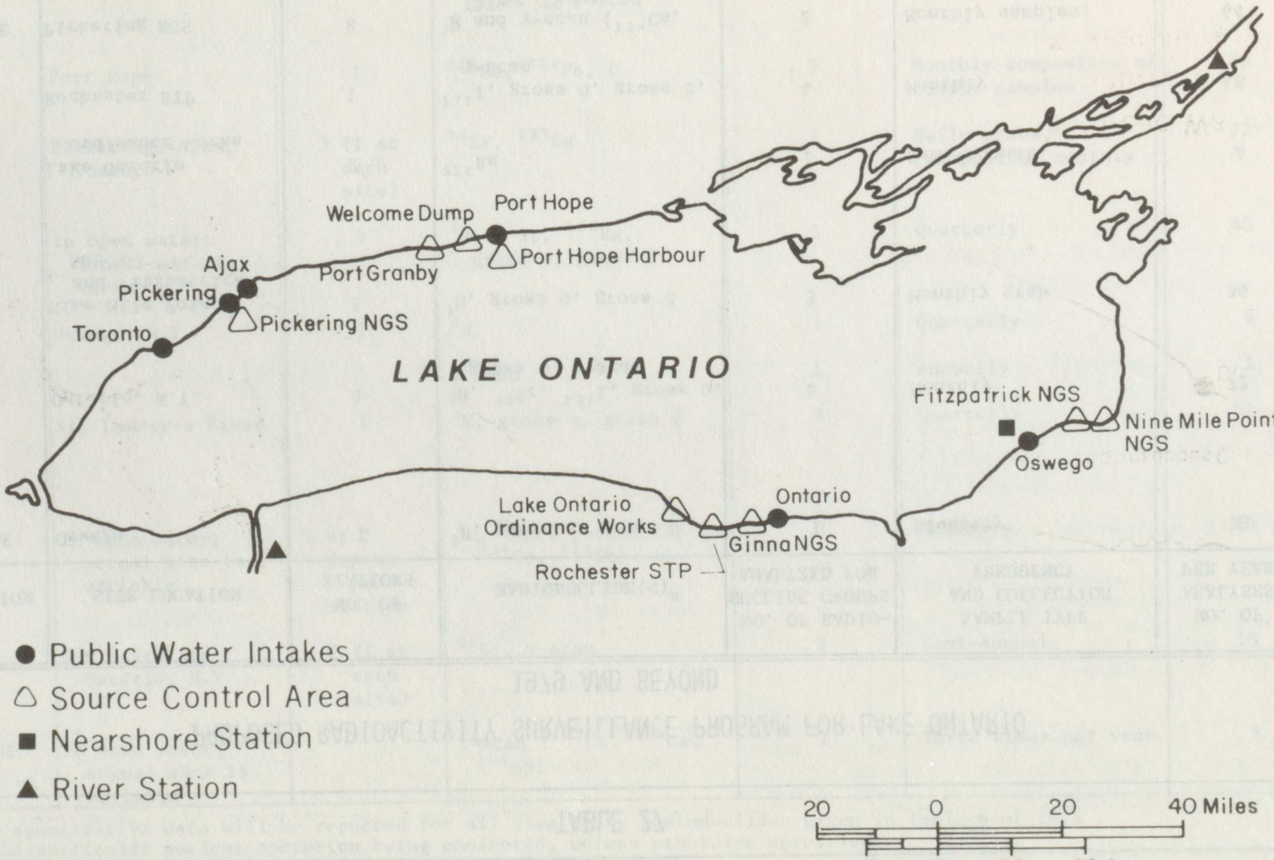


Figure 6

SAMPLE COLLECTION LOCATIONS FOR RADIOACTIVITY SURVEILLANCE IN LAKE ONTARIO



(Locations are Approximate)

TABLE 27

PROPOSED RADIOACTIVITY SURVEILLANCE PROGRAM FOR LAKE ONTARIO
1979 AND BEYOND

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Source Control Area	New York DEC	Oswego	1	^{3}H, gross α, gross β	3	Biweekly	78	Station is water intake located upstream of Nine Mile Point and Fitzpatrick NGS's.
	New York DEC	Ontario, N.Y.	1	^{3}H, ^{90}Sr, ^{131}I, gross α, gross α, γ-scan	6	Monthly	72	Station is water intake located near Ginna NGS.
	New York DEC	Nine Mile Point and Fitzpatrick NGS's	1	^{3}H, gross α, gross β	3	Monthly grab	36	Station at New Haven, on Demster Beach Road. Downstream of both NGS's.
	New York DEC	Lake Ontario Ordinance Works	2	^{226}Ra	1	Semi-annual	4	
	New York DEC	Rochester STP	1	^{131}I, gross α, gross β, γ-scan	4	Monthly	48	Hospitals, etc.
	Ontario MOE and MOL	Pickering NGS	8	^{3}H and γ-scan (^{134}Cs, ^{137}Cs, ^{60}Co)	2	Monthly samples, composited quarterly	64	
	Ontario MOE and MOL	Port Granby	8	^{226}Ra, ^{228}Ra, ^{230}Th, ^{210}Pb	4	Monthly samples, composited quarterly	128	
	Ontario MOE and MOL	Welcome Dump and Port Hope Harbour	13 (4 for Welcome, 9 for Port Hope)	^{226}Ra, ^{228}Ra, ^{230}Th, ^{210}Pb	4	Monthly samples, composited quarterly	208	

[a] "γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Table 27 cont'd.

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIONUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Water Intake	New York DEC	Oswego	1	^{3}H, gross α, gross β	3	Biweekly	78	See also SCA section. Finished water.
	New York DEC	Ontario, N.Y.	1	^{3}H, ^{90}Sr, ^{131}I, gross α, gross α, γ-scan	6	Monthly	72	See also SCA section. Raw water.
	Canada NH&W	Port Hope	1	^{226}Ra, ^{210}Pb, U	3	Monthly composites of daily samples	36	
	Canada NH&W	Pickering, Ajax, Toronto	3 (1 at each site)	^{90}Sr, ^{137}Cs	2	Daily grabs, composited monthly	72	Raw water.
Open Water and Near-shore	U.S. EPA	In open water; actual site is variable	2	^{3}H, ^{90}Sr, ^{226}Ra, gross α, gross β	5	Quarterly	40	
	U.S. EPA	Oswego, N.Y.	1	^{3}H	1	Quarterly	4	
				γ-scan	1	Annually	1	
	New York DEC	St. Lawrence River	1	^{3}H, gross α, gross β	3	Quarterly	12	Observed data can be considered as integrated value for Lake Ontario.
	Canada DFE	In open water; actual site is variable	3; 2 depths per station	^{3}H, ^{90}Sr, γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	3	Annually	18	
Biota	New York DEC	New Haven and Ontario, N.Y.	2 (1 at each site)	^{90}Sr, γ-scan	2	Semi-annual	16	Fish, aquatic vegetation.
	Canada DFE	In open water; actual site is variable		γ-scan (^{137}Cs, ^{134}Cs, ^{125}Sb)	1	Three times per year	3	Whole fish.

[a]"γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

Table 27 continued

TYPE OF PROGRAM	JURISDICTION	SITE LOCATION	NO. OF STATIONS	RADIONUCLIDE(S)[a]	NO. OF RADIO-NUCLIDE GROUPS ANALYZED FOR	SAMPLE TYPE AND COLLECTION FREQUENCY	NO. OF ANALYSES PER YEAR	COMMENTS
Biota (cont'd.)	Canada NH&W	Port Hope	1	^{226}Ra, ^{210}Pb, U	3	Twice per quarter	24	Fish.
Sediment	Canada DFE	In open water; actual site is variable	2	^{137}Cs, ^{125}Sb, other γ-emitters	2	Irregular - preferably annually. Core sample.	4	

[a]"γ-scan" implies that quantitative data will be reported for all γ-emitting radionuclides given in Table 6 of 1976 Appendix D (1), for the particular nuclear operation being monitored, unless otherwise specified.

TABLE 28

RADIOACTIVITY SURVEILLANCE - COST SUMMARY

JURISDICTION	PRESENT OPERATING COST	COST TO UPGRADE	PROJECTED COST TO OPERATE UPGRADED PROGRAM	TOTAL NUMBER OF ANALYSES PER YEAR	COMMENTS
U.S. EPA	0	5,000	80,000	360	
Minnesota	0	0	0	9 - 19	Program to commence 1980 at latest.
Wisconsin	30,000	45,000	55,000	118	Cost figures are for entire state program. They also include sampling of other media such as air, well water, fish, soil, vegetation, and milk associated with power plant operation.
Illinois	6,120	0	7,168	116	
Indiana	2,500	35,000	30,500	82	Upgrading: salary for radiochemist, overhead, quality control, equipment and supplies.
Michigan	42,900	128,200	38,300	320	Present: Personnel, equipment, and supplies. Upgrading: First year of operation; includes inflation factor. Projected: Second year of operation; includes inflation factor.
Ohio	2,100	80,000	24,000	472	Upgrading: Possible instrumentation cost.
Pennsylvania	0	0	2,500	36	Analysis only.
New York	18,000	14,425	32,500	597	Upgrading: for ion exchange stations, sampling (parameters and STP's).
Canada DFE	15,000	0	15,000	84	
Canada NH&W	9,000	8,000	17,000	360	
Ontario	30,000	120,000	165,000	640	Present: Sample collection and data storage only. Upgrading: Capital funds for lab equipment and modifications. Projected: Includes manpower, maintenance, and supplies.

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